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Remote Site Waste Management

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Technology for Waste Treatment at Remote Army Sites

by
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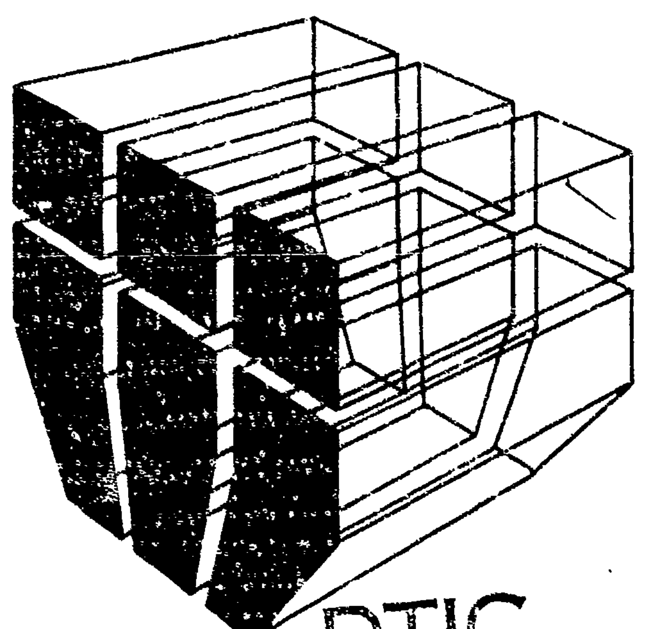

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This report examines the problems associated with traditional methods for disposing of human wastes at remote Army sites. Two alternative technologies--aerated vault latrines and composting latrines--offer substantial advantages over traditional methods such as pit latrines, unaerated vault latrines, and chemical latrines. These two technologies are analyzed in terms of their costs, operation and maintenance requirements, Army applicability, and user acceptability. Based on the information obtained from the research, recommendations are made regarding applications of these technologies to use at remote Army sites. Information is provided on selection, design, operation, and maintenance of the recommended technologies.

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FOREWORD

This work was performed for the Office of the Assistant Chief of Engineers (OACE) under Project 4A162720A896, "Environmental Quality Technology"; Task Area A, "Installation Environmental Management"; Work Unit 039, "Remote Site Waste Management." The investigation was performed by the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (USA-CERL). The OACE technical monitors were Mr. R. Newsome and Mr. Tom Wash (DAEN-ZCF-U).

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1 INTRODUCTION

Background

Remote site waste management is an area of environmental engineering that has traditionally maintained a low profile on military installations. However, as military installations upgrade training facilities which often date from World War II, the problem of achieving aesthetically and environmentally acceptable disposal of remote site waste at an affordable cost is becoming a larger concern.

On Army installations, water and sewer lines are provided only in the cantonment areas, where there are enough people and activities to justify expenditures for sewage collection and treatment. At remote military sites (e.g., firing ranges, bivouac areas, recreation areas, and guard stations), four technologies have traditionally been used to treat human waste: trenching and cat holing, pit latrines, vault latrines, and chemical latrines.* However, these approaches produce problems of offensive odors, groundwater and soil pollution, nuisance insects, and the need for proper maintenance, all of which affect user/troop acceptability.

Overall costs for remote site waste management can be high. Several installations pay more than $100,000 per year for chemical and vault latrine rental and servicing, with one installation spending $360,000 annually for chemical latrines.

Previous research by the U.S. Army Construction Engineering Research Laboratory (USA-CERL) suggested use of the aerated vault latrine and the composting latrine for providing an enhanced user environment, lower levels of environmental pollution, absence of offensive odors, and ease of operation and maintenance.[1] These technologies were chosen as being capable of handling continuous use by a large population in a relatively short timeframe. Both reduced odors tremendously, required minimal maintenance, and were suitable for retrofit and new construction. Both technologies were recommended in the appropriate context. Early investigation indicated that greater emphasis should be placed on use of composting latrines; however, further research revealed that aerated vault latrines were more economical and required less maintenance. Minimal maintenance is an essential consideration where there is a shortage of manpower, such as at Army installation Directorates of Engineering and Housing (DEH). Aerated vault latrines were found to be as popular as composting latrines, as well as being much cheaper.

An evaluation of a third technology--Shasta latrines--(Appendix A) will be prepared by the U.S. Army Cold Regions Research and Engineering Laboratory. The Shasta units are being modified and may be a viable alternative in the future.

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*NOTE: The term latrine is used for consistency in this report. Readers will understand that latrine and toilet are interchangeable in many situations.

[1] E. D. Smith, et al., *Appropriate Technology for Treating Wastewater at Remote Sites on Army Installations: Preliminary Findings*, Technical Report N-160/ADA142096 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1984).

Objective

The objectives of this report are to (1) examine the problems associated with traditional methods of managing human wastes at remote sites--pit latrines, vault latrines, and chemical latrines; (2) analyze alternative remote site waste management technologies and recommend the most appropriate options for Army applications; and (3) provide information on selection, design, and operation and maintenance of the recommended technologies.

Approach

Several Army installations were surveyed to monitor use of and satisfaction with various remote site waste treatment technologies. Detailed information was obtained on the treatment processes used in aerated vault and composting latrine technologies. The information obtained on health aspects, costs, and operation and maintenance practices was used to propose recommended applications for these two alternative technologies, as well as guidance for selecting, operating, and maintaining appropriate systems.

Mode of Technology Transfer

It is recommended that information from this study be incorporated as additions to Technical Manual 5-814-3, *Domestic Wastewater Treatment*. The information in this report will also be issued as an Engineer Technical Note.

2 TRADITIONAL WASTE DISPOSAL METHODS AT REMOTE SITES

U.S. Army Training and Doctrine Command (TRADOC) and U.S. Army Forces Command (FORSCOM) installations are the primary Army users of remote site waste treatment technologies. These installations were surveyed by telephone to determine current practices, problems, and associated costs. Appendix B provides the results of individual installation interviews.

Some installations permit troops to dig slit trenches and cat holes (waste is deposited in a small hole and covered with soil) in selected areas and situations. These are used because they are an economical means of disposing of human waste and primarily because they afford soldiers the training and experience of providing field-expedient latrines. The training aspect is important and is encouraged where conditions permit and where there is no hazard to public health or the environment. Conversely, where troops have limited access to a limited amount of training land, such a policy is unworkable. At firing ranges, where 160 to 250 troops train 5 days a week, 50 weeks a year, it is vital to have semi-permanent latrine facilities to avoid an environmental problem.

Chemical latrines are the most extensively used option. FORSCOM and TRADOC installations use an estimated 5000 chemical latrines per year, with training installations being the biggest users.

Chemical latrines (Figure 1) are readily available, can be easily moved, and numbers can be increased or decreased as needs change. Since training requirements vary greatly at most installations, both in time and location, chemical latrines are a flexible solution to field needs. They are used at ranges, training areas, buildings not connected to sewers, remote work sites, gate guard posts, special events such as ceremonies, open houses, and parades, sports events, and field and recreation areas. Five installations own some or all of their chemical latrines, with the remainder contracting for them. Most installations lease the chemical latrines from a contractor, who provides the latrines and necessary servicing, such as pumping, cleaning, and resupply of toilet paper. All installations contract for servicing due to in-house personnel limitations. (This will continue to encourage contracting the servicing of latrines.)

The costs of leasing chemical latrines vary greatly. Most installations pay a unit price for the latrine and servicing; others pay separate prices for placing and picking up the latrine, servicing it, and relocating it. Unit prices usually vary according to the length of rental and frequency of servicing. The longer the rental time, the lower the price. Servicing frequency varies from daily to once a week. Some installations set a regular schedule, and others call for service as it is required. Typical prices range from \$40 to \$50 per month, which includes rental and twice weekly servicing.

Users often complain about odors from the chemical latrines. This is usually due to poor or delinquent servicing by the contractors. Quality of service varies among contractors at the local installations, which underscores the importance of proper contracting procedures. Most installations seemed satisfied with contractor work.

The outhouse and waste collection chamber of chemical latrines are a single unit; chemicals control some of the odor from the stored waste. The light fiberglass construction of these latrines makes them especially susceptible to vandalism. Virtually all installations reported vandalism. The latrines are run over by vehicles, shot at, burned, and stolen. Several latrines were also damaged in attempts to lift them with a forklift.

Figure 1. Chemical latrine.

Not all the abuse is by soldiers. Some is apparently caused by hunters or unauthorized people, particularly at open posts. Chemical latrines in remote training areas appear to be most susceptible to vandalism. A number of installations reported that chemical latrines have been blown over by high winds.

Chemical latrines also suffer from inadequate maintenance, and on a warm day even the best-maintained units give off foul odors. Costs for chemical latrines, including rental and servicing vary widely, ranging from $30 to $150 per unit per month. One installation pays $5800 per unit, per year. Daily or short-term rentals can be $30/day or more.

Contractors have complained that users throw trash, including ammunition into the latrines. One installation indicated difficulties in coordinating the movement and servicing of chemical latrines with changing locations of troop units. Despite a policy to notify DEH 2 weeks in advance, the units often submit requests for moving the latrines at the last minute. Also, troops must guide the servicing contractor to the latrines, and if the guides show up late or not at all, the contractor is delayed. Another installation reported that troops sometimes move the latrines after the contractor has installed them. The contractor is then unable to find the unit for removal or servicing.

Unaerated vault latrines--outhouses over concrete chambers--are used most often for remote site treatment on Army installations. However, these units give off foul odors caused by anaerobic decay of wastes, especially during warm weather. The stench attracts flies and other disease vectors, such as mosquitoes. At many installations, seats for these latrines are no more than holes cut in a plywood board, which makes sanitation difficult. Maintaining unaerated vault latrines can be expensive and time-consuming. The waste must be pumped into a transport truck and properly disposed of, which can cost from $75 to $350 per servicing unit. Cans, bottles, and ammunition thrown into the

latrines often clog disposal hoses and must be removed by hand. Disposal of the highly concentrated wastes can also be a shock load on the sewage treatment plant.

Most installations that use vault latrines (Figure 2) contract for servicing, with only one installation pumping the vaults themselves. Although the cost of servicing vault latrines usually includes just pumping, it is hard to compare prices at different installations. Unit prices vary according to vault volume, and most people interviewed did not know the volume of the tanks. The prices also reflect pumping frequency. Some installations have them pumped regularly, and others do it as needed. In some cases, pumping of vaults is part of a large contract to pump septic tanks and grease traps, and the prices for the vault pumping are not broken out. Prices are typically $60 to $80 for servicing a 500-gal* vault, with one installation paying $350 for servicing of a 1000-gal vault.

Pit latrines (Figure 3) are used on many installations, sometimes unknowingly. A pit latrine is usually defined as a pit dug to receive waste with an outhouse-type building resting over it. When the pit is full, the building is removed, the pit filled in and covered with soil, and the building transported to a new location. These latrines are extremely cheap to construct, but have many potential problems. If located too close to the water table, they are a source of groundwater contamination. They are also excellent breeding sites for many insect disease vectors, such as flies and mosquitoes. Several vault latrines constructed many years ago have wood sides and nonsealed bottoms, which permits free exchange of the wastes with local groundwater.

*Metric conversion f[illegible] are provided on p 82.

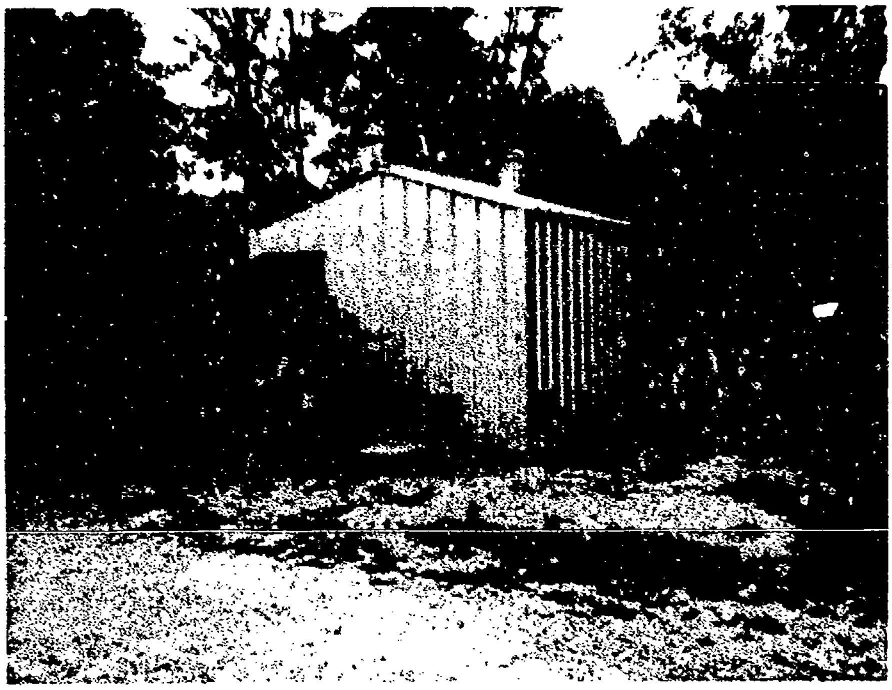


Figure 2. Vault latrine.

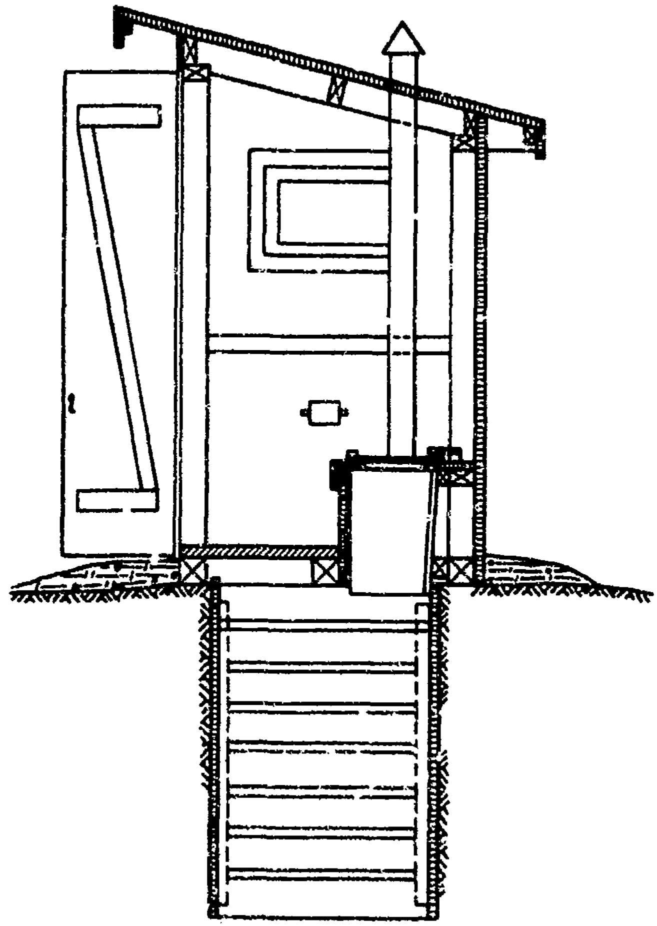


Figure 3. Pit latrine.

3 DESCRIPTION AND RECOMMENDED APPLICATIONS OF COMPOSTING LATRINES AND AERATED VAULT LATRINES

This chapter briefly describes important characteristics of aerated vault latrines (Figure 4) and composting latrines (Figures 5 and 6)--the two technologies chosen as possible alternatives to traditional waste treatment methods. Also presented are recommended applications of the various remote site waste treatment technologies. Table 1 presents a series of short questions and answers on the various technologies.

Composting Latrines

Composting latrines have been used for more than 30 years. Although most applications have been in private residences, their use in public facilities, such as national and state parks, highway rest stops, and public beaches is increasing. It appears that composting, if given proper attention, can work even in public facilities where the typical user is not concerned with proper system operation.

Composting--the controlled decomposition of organic material into a humus-like end product--takes place by aerobic decomposition or anaerobic fermentation. In these processes, bacteria, fungi, molds, and other saprophytic organisms feed on organic material, including human waste, and convert them to a more stable form.

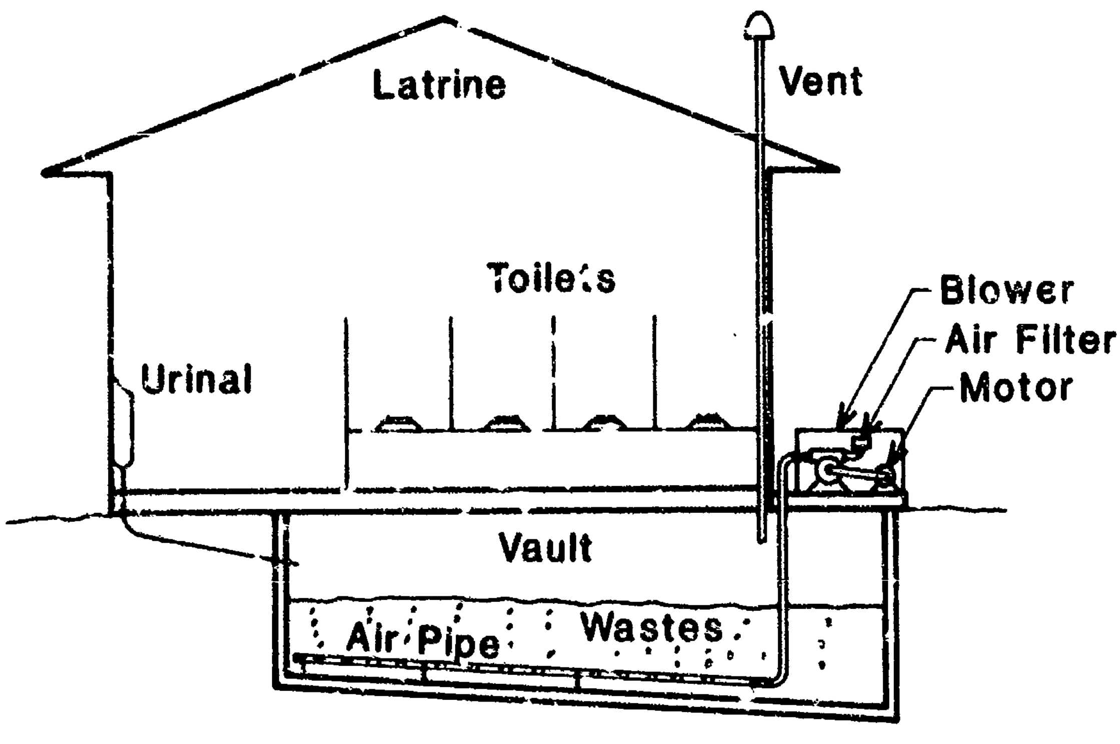


Figure 4. Aerated vault latrine.

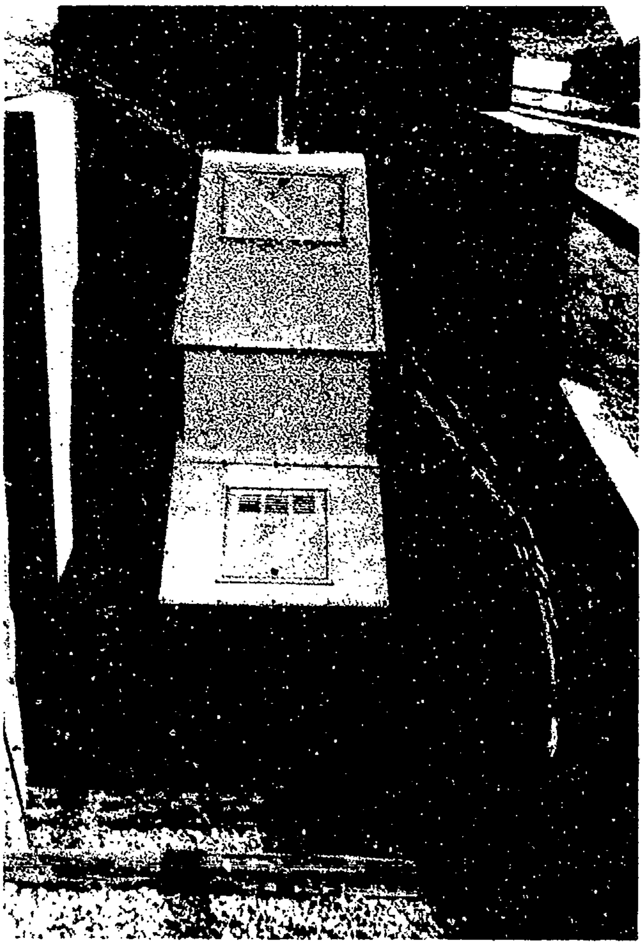


Figure 5. Composting latrine.

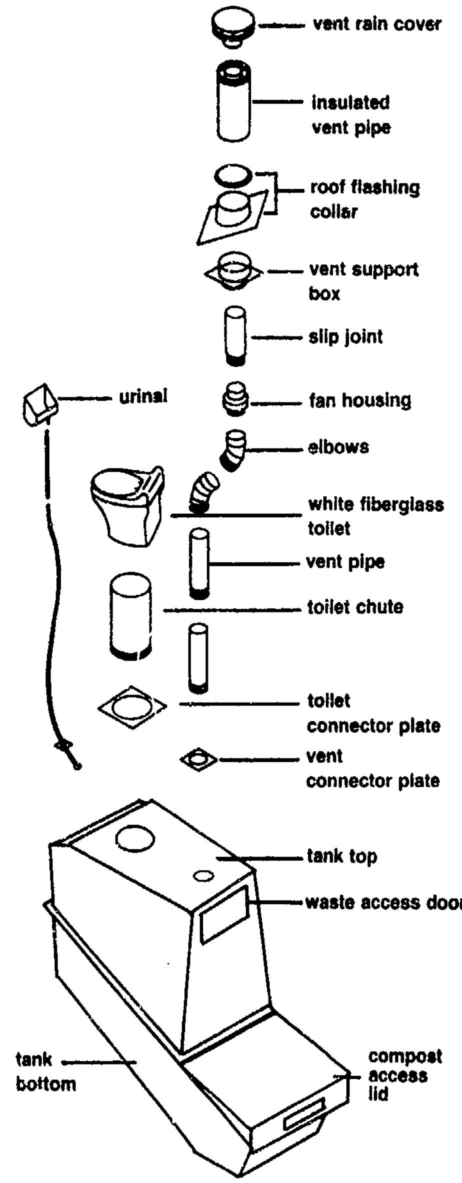


Figure 6. Composting latrine components. (From *Planning, Installation and Operation Manual for Public Facilities* [Clivus Multrum, USA, 1983]. Used with permission.)

Aerobic decomposition takes place very efficiently in the presence of oxygen. The process smells "earthy" and generates temperatures high enough to kill portions of its own microbial population, including enteric pathogens. However, large, continuous composting latrines do not generate high temperatures; instead, they rely on time and a hostile environment for pathogen destruction. In the absence of oxygen, anaerobic composting occurs slowly, producing offensive odors. A composting latrine is designed for continuous aerobic decomposition of human wastes. No water is used for flushing, so only night soil (fecal matter, urine, toilet paper, and bulking agent) is introduced into the composting chamber.

Table 1

Application of Remote Site Waste Treatment Technologies to Army Installations: Questions and Answers

Question	Short Answer
1. Where and when can composting latrines be used on Army installations?	Composting toilets can be used at remote sites with no regular water supply and sewage facilities; when existing vault latrines or pit latrines are unsanitary; when water supply and sewage collection will not be provided soon; when no electricity is available at the site (can also be used where electricity is available); where road access for pumping is difficult.
2. Where and when can aerated vault latrines be used on Army installations?	Aerated vault latrines can be used at remote sites with no regular water supply and sewage facilities; when existing unaerated vault latrines or pit latrines are aesthetically unacceptable or unsanitary; when water supply and sewage collection will not be provided soon; when electricity is available; where a pumper truck would have access.
3. Are composting latrines reliable in a variety of climates and under highly fluctuating loadings?	The system allows aerobic decomposition of organic waste and significant reduction of pathogenic organisms in the waste concurrent with physical volume reduction by evaporation. Its effectiveness increases with the temperature. Cold regions have very low composting rates. There the latrines serve more or less as waste containment units until the spring thaw allows composting to resume. The system can tolerate high fluctuations in loading as long as the recommended daily maximum load and the annual load are not exceeded. Good insulation, passive solar heating, and an external heat source can be used to increase the unit's effectiveness.
4. Are aerated vaults reliable in a variety of climates and under highly fluctuating loadings?	The system will tolerate constant large-volume use until the vault is full. High solids loading and constant aeration prevent freezing in cold climates. When properly located and protected from the elements, the motor/blower unit requires minimal maintenance.
5. What are the appropriate criteria for selection of composting latrines?	Manufacturers recommend a specific number of uses, depending on temperature and climate, for various sizes of composting toilets. Both maximum daily use and annual use should be within the system's allowable limits.

6. What are the appropriate criteria for selection of aerated vault latrines?

The technology is not limited technically. Sizing of vault latrines is by anticipated use (i.e., training range, guard station, etc.).

7. What is the capital cost for a composting latrine?

A two-seat latrine using one tank allowing 25 fulltime users costs about $6500, plus support, superstructure, and installation for a total of about $16,000. A double-tank unit with building would be $35,000 to $41,000, and a triple-tank installation would be $60,000 to $70,000.

8. What are the associated capital costs for an aerated vault latrine?

Converting an existing unaerated vault latrine into an aerated vault latrine costs about $2000. New construction of a complete aerated vault latrine with six to eight seats costs about $15,000. Conventional vault latrines are about $13,000.

9. Are composting latrines easy to install and start up? What about site preparation?

Installing a large unit takes 32 man-hours plus another 80 to 100 man-hours for superstructure installation. Site preparation and excavation could take 48 to 80 man-hours, depending on the local conditions. Experienced personnel can reduce the installation time somewhat. Manufacturers provide simple, specific instructions on startup.

10. Are vault aeration units easy to install and start up? What about site preparation?

Installation of a prefabricated motor/blower unit takes about 12 man-hours for retrofit operation. Site preparation, excavation, and superstructure installation will be similar to those for composting latrines, except that somewhat fewer man-hours are required. Use of experienced personnel will reduce time requirements.

11. How much space does a composting latrine require?

The largest unit, which has two seats plus one urinal, measures 104-1/2 x 45 x 84 in. high. Another 8-in. minimum clearance above the unit is required. To minimize space and cost, the Army can design the superstructure to fit single or multiple composting units. Partially burying the units increases insulation and reduces the height. New configurations are becoming available.

12. What are the extra space requirements for vault aeration?

The aboveground box is about 14 by 36 in. However, there should be ample room around it for maintenance. It can be located outside or inside the building.

13. What are a composting latrine's operational and maintenance requirements?

Required are: daily addition of bulking agent; monthly stirring of the pile; semi-annual removal of compost; weekly check for fan operation; removal of excess liquid.

14. What are the operational maintenance requirements of an aerated vault latrine?

Required are: monthly check of drive belt; and semi-annual change of air filter; replacement of vanes and bearings (2 hr) every 2 years; replacement of motor every 5 years; pumpout of vault as needed.

15. What are the skill and manpower requirements for composting latrines?

Low skill; requirements are 1 man-hour/week-unit, including 10 man-minutes/day for adding bulking agent. Turning the pile takes 20 man-minutes/month. Removal of compost requires 2 man-hours twice a year.

16. What are the skill and manpower requirements for vault aeration?

Low skill; contract with septic pump cleaner for pumpout. Preventive maintenance may require periodic use of mechanics.

17. What are composting latrine limitations?

Limitations are: inability to remove toxic and nonbiodegradable chemicals; slight chance of fire hazard from lit cigarette butts; low temperatures stop the composting process and reduce capacity; only accepts human and some kitchen waste. Greywater should be excluded. Severe overuse or poor maintenance may cause unit failure, requiring cleanout and restarting of composting.

18. What are the system's limitations for aerated vault latrine units?

The system requires electricity. Power failure for an extended time will revert unit to conventional unaerated vault latrine. Addition of toxic chemicals may kill aerobic organisms, thus causing unit to function as a conventional vault latrine.

19. How do composting latrines and aerated vaults compare with more conventional remote site waste treatment units?

Both are superior to pit latrines, cat holes, chemical latrines, and conventional unaerated vault latrines because units are more sanitary and user-acceptable, and they protect the environment.

20. What are the advantages/disadvantages of composting latrines?

Advantages: Composting latrines provide more sanitary conditions and improved aesthetics for users without having to wait for water and sewage systems to be developed in remote areas; are simple to operate and maintain; can be phased in according to budget availability; conserve water; have low energy requirements; have low operating and maintenance costs.

Disadvantages: Composting latrines have a high initial cost (capital cost) per troop, particularly in cold regions (more units are required to contain the waste because of the very slow composting rate). Possible odor, fly, and fire hazard problems may result from improper

service and management. Residue must be removed carefully to minimize health risks. Users must not misuse the unit (e.g., trash, lit cigarette butts, and toxic chemicals must not be thrown in). Maintenance is very important and should be regular. Overuse can result in failure. Require electricity for ventilation. Ventilation is extremely important for proper evaporation of liquid.

21. What are the advantages/ disadvantages of aerated vault latrines?

Advantages: The advantages of aerated vault latrines are the same as for composting latrines except for their energy requirement. They are more flexible in handling large numbers of users and usage fluctuations, requiring only more frequent pumpout. Retrofit applications can be made at low initial cost. New construction has much lower capital costs for equivalent capacity.
Disadvantages: Units require electricity.

22. What is the energy consumption of composting latrines?

Composting latrines require 14 W per unit for the exhaust fan. The power consumption is insignificant and could be handled by an add-on $1200 solar unit.

23. What is the energy consumption of an aerated vault unit?

Energy to maintain constant operation of the 3/4-hp motor/blower unit costs $480 per year. On/off cycling would slightly reduce power costs, but is not recommended.

24. What are the opinions of composting latrine owners and users?

A survey of public facility owners and operators generally reveals favorable reactions Owners are satisfied with the performance and simplicity of O&M requirements. Most are aware that neglecting service and maintenance leads to odor and insect problems.

25. What are the opinions of aerated vault users and owners?

Reaction is extremely favorable.

26. What is the life expectancy of composting latrines?

Most manufacturers have a 5-year warranty for the unit, except for mechanical parts, which are generally guaranteed for 1 year. Life expectancy of the fiberglass unit is 20 years; however, many European units have been used for more than 30 years.

27. What is the life expectancy of an aerated vault unit?

So far, it is undetermined. The oldest units have been used for 12 years. Piping should last indefinitely, while the motor replacement is recommended every 5 years.

28. What about masking agents as an alternative to odor control problems?

Masking agents may provide a lower cost solution to an odor control problem. Each installation would have to experiment with the products, since results are highly variable. For example, a masking agent may be effective at one temperature and fail at a higher one. Downstream effects must also be considered, since many of the compounds are bactericidal.

Waste treatment by a continuous composting latrine relies on the natural process of decomposition, which requires 1 to 2 years. The process takes place in a large chamber (Figure 6), which is generally installed on a slope so that the waste slowly moves to a bottom removal area. Wastes are combined with bulking agents (e.g., grass clippings, leaves, sawdust, finely chopped straw) to form a mass that can be reduced into humus and continuously decomposes until disposed of. These bulking agents aid composting both physically, by loosening the pile for improved air diffusion, and biologically, by providing a carbon source for the aerobic bacteria.

Composting, particularly the evaporation aspects, significantly decreases the volume of wastes, so the final amount to be disposed of is relatively small. For example, 8 cu ft of end product is removed annually from a continuous composter serving 15 people daily throughout a summer season. A vent pipe and fan constantly remove carbon dioxide, water vapor, and ventilation air from the chamber. Since most of the liquid is removed through evaporation, there is usually little danger that untreated wastes will reach groundwater or surface water.

Composting latrines may be used in areas where water is available but in short supply, and where electricity is readily available; however, they are best suited for areas without water. They can use a solar energy cell for electrical supply.

The performance of composting latrines at Army facilities depends on the use of proper composting techniques and efficient removal of excess liquid. Appropriate operation and maintenance is also critical.

Performance may also be affected by state and local regulations on composting latrines. Such regulations may govern the use of the unit itself, disposal of excess liquid, and ultimate compost disposal. The Facilities Engineer (FE) should find out whether these regulations apply to latrines installed at remote sites on Army posts.

Composting latrine design is usually based on 25 fulltime users for the largest tank. This equates to 75 persons per day, since training ranges function for one 8-hour shift per day.

Performance of the compost latrine in a specific situation must also be considered. Several site-specific factors affect the performance of composting units: climate, soil conditions, groundwater table, and availability of maintenance personnel, energy, and water.

Proper composting and volume reduction depend on temperature and adequate ventilation. In colder climates, the composting chamber may have to be insulated to maintain adequate composting temperatures; otherwise, the latrine serves only as a storage chamber. In extremely cold climates, it may even be necessary to install a heating system. If the structure is positioned so that it receives as much sun as possible,

solar glazing may provide enough heat. Except in hot arid climates, solar glazing is recommended whenever a unit is to be used during the winter.

In addition to supplying a continuous flow of air to the compost pile, adequate ventilation reduces odors and removes moisture. The amount of moisture that can be removed depends primarily on the climate (temperature and humidity). A fan must be operated continuously. Fans usually need electricity, but direct current (DC) or solar units may be used when no alternating current (AC) power is available.

Breakdown (or treatment) of wastes in the composting latrine occurs naturally, by aeration, without additional water or chemicals, using a series of air channels and baffles and a continually operating fan (Figure 7). Addition of the bulking material is essential for proper operation of the unit. Bulking material should be added at the rate of 1 gallon for every 100 uses, although this is site-specific and the manufacturer's guidance should be followed. If the facility is used every day, it is advisable to add bulking material at least every other day, although more frequent addition is desirable. The material can be added either by a contractor, or by troops during routine latrine maintenance. It is also important to rake and thoroughly stir the waste pile once a month to ensure proper operation. Liquid buildup is a major concern on military and other public installations, and drainage systems must be properly operated to avoid process failure. The only other maintenance required is semiannual removal of the compost product and routine checks of the system. If proper composting has occurred, the end product should be reasonably safe to handle. However, it is recommended that this material be handled carefully and disposed of in a landfill to prevent transmission of diseases (Chapter 7).

The following operation and maintenance procedures are recommended:

1. Keep the toilet seats closed when not in use. (This avoids short circuiting of air flow.)

2. Keep the pile moist (check when raking the pile).

3. Remove the liquid end product (inspect each month). Check drain to leach field if present.

4. Add bulking agent every other day based on a rate of 1 to 2 ft per 1000 uses, typically 1 gal per tank, half down each of the two chutes.

5. Remove the compost as needed (after 1- to 2-year startup period, up to 15 cu ft of end product may have to be removed annually). Generally, semi-annual removals are appropriate.

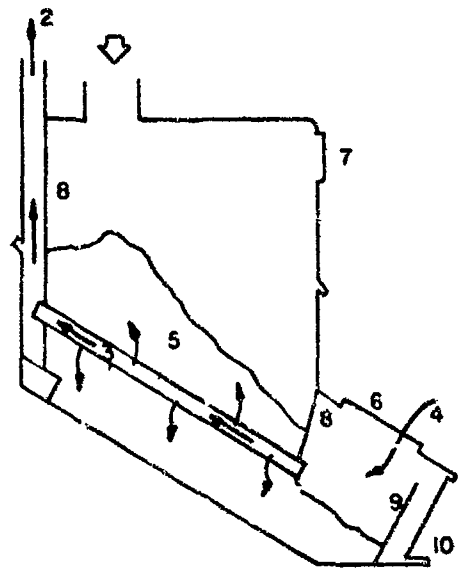
6. Maintain the ventilation system (remove fan and clean vent stack once a year).

7. Prohibit smoking and fires near the units.

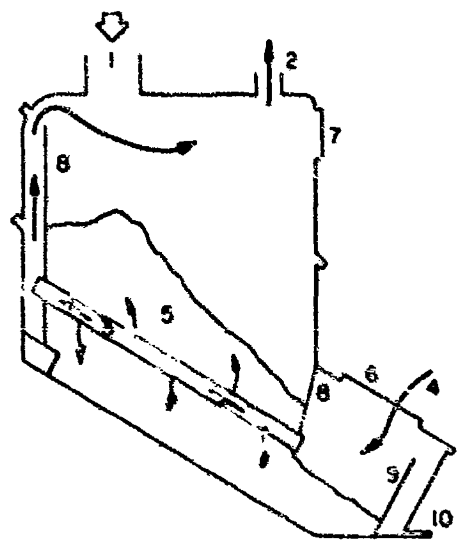
8. Maintain proper temperatures.

9. Inspect the tank support every year.

10. Clean the toilet chute and urinal properly. (Use a mild detergent, not toxic chemicals that could interfere with the composting process.) Cleaning of toilet seat and adjacent area should be daily or as frequently as possible.



a. Alternative air-flow pattern (Purdue pattern).



The Arrows indicate Air Flow Through the Toilet

Key: 1. Waste Chute — 6. Emptying Hatch
2 Vent Pipe with Fan — 7. Inspection Hatch
3. Air Duct — 8. Waste Baffles
4. Air Inlet — 9. Liquid Baffles
5. Composting Mass — 10. Liquid Drain

b. Typical composting latrine.

Figure 7. Composting chamber.

11. Check for odor once a month. If odor is present:
    a. Check the fan.
    b. See if the seat closers are operating.
    c. Check for excess liquid buildup.
    d. Make sure the bulking agent is reaching the pile (not accumulating directly under the chute.

12. Rake the pile monthly.

According to one manufacturer, if carbonaceous matter cannot be added every other day, but must be added in larger quantities less frequently, it should be "raked in" to the pile to ensure the proper carbon-nitrogen ratio throughout the pile. Most installations drain excess liquid which filters through the system to a leach field. Where this is unacceptable, a holding tank and/or manual removal are required.

For Army installations, some of these suggestions probably will be unnecessary. For example, with anticipated heavy urine loading, the pile will always be moist.

There are currently two manufacturers of large composting latrines: Clivus Multrum USA, and Compost Toilet Systems (CTS). Costs for a large composting latrine are about $6500 (Clivus Multrum) or $4400 (CTS) for a unit that includes the largest tank, two toilets, one urinal, and installation hardware. Clivus Multrum units are available through the General Services Administration (GSA), with 8, 10, or 12 percent discounts, depending on the number of units purchased. CTS offers a 5 percent GSA discount. Units also require a building to house them. Of course, units can also be purchased through competitive bids, which may change the price. To service a typical firing range, Clivus Multrum recommends a building with three tanks which would cost $60,000 to $70,000 (1985 dollars). Turnkey units installed at Fort Jackson, SC (Figure 8) training ranges contained two tanks with fixtures and hardware and cost $133,000 for five double units, an average of about $27,000 each at 1984 prices. However, two USA-CERL researchers also donated labor toward the project which was done in 1 week. Much of the construction had been prefabricated.

Table 2 presents general maintenance instructions for composting latrines. Although they are based on one manufacturer's information, they are applicable to other systems. Appendix K has a suggested scope of work for contracting out O & M.

Vault Aeration

Bubble aeration systems have functioned successfully for many years. The concept involves modifying a new or existing vault latrine to supply air to the waste by installing a motor/blower unit and connecting it to a perforated pipe attached to the vault floor (Figure 4). Air continuously supplied to the waste supports the growth of aerobic organisms, which break down the wastes into carbon dioxide and water. Aerobic decomposition is about four times faster than anaerobic decomposition. Preventing anaerobic decay also greatly reduces the odor in the latrine, providing a far more acceptable user environment. Addition of a vent fan and stack are also vital components of optimizing this technology.

A 200-cu-ft vault requires about 15 cu ft/min of air for proper waste treatment. The air can be supplied by a positive displacement blower belt driven by a 3/4-hp electric motor. A 3/4-in.-diameter PVC or cast-iron pipe drilled with one hundred 1/8-in.-diameter holes spaced evenly along its length distributes the air. This pipe sits about

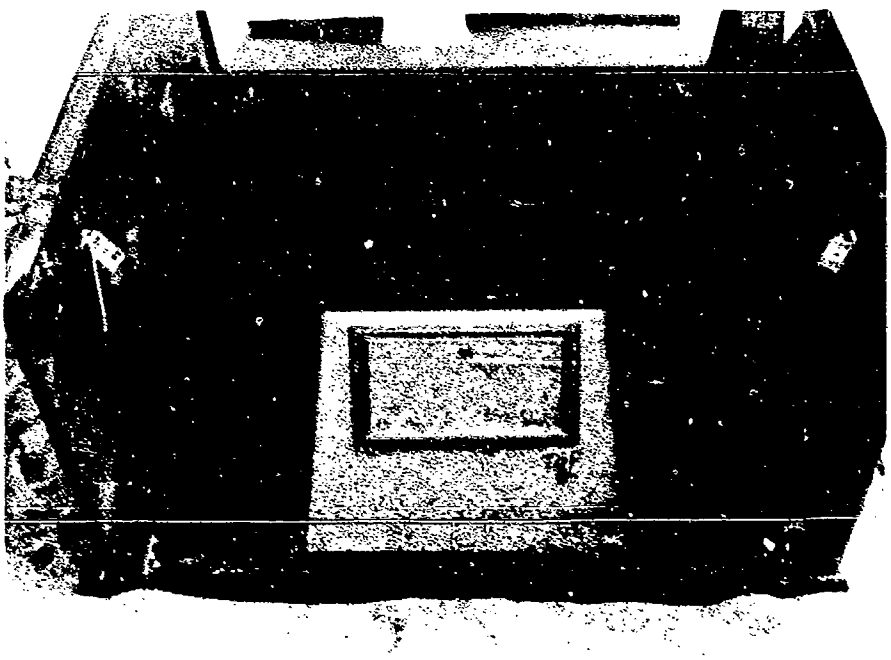


Figure 8. Composting latrines units at Fort Jackson, SC.

Table 2

Sample Instructions for Servicing Composting Toilets on Military Installations
(Information was obtained through personal communication with Clivus Multrum, USA, Inc., and supplemented by USA-CERL experience.)

I. ADDITION OF BULKING AGENT

Once a day (or approximately every 100 uses), add to each toilet chute (assuming 2 chutes on 1 tank) about 1.9 L of coarse sawdust or wood shavings (not chips).

Every month, inspect the height of the waste pile through the waste access door on the front of the tank. If the air channels are exposed, add enough bulking agent to cover them. If the waste appears to be piling up and clogging the toilet chutes, then rake over the waste until it is evenly distributed. The waste pile should be moist with a crumbly texture. If it appears to be compact, increase the amount of bulking agent, but not more than double the amount indicated above. Waste pile should be thoroughly raked and mixed at this time.

II. MOISTURE CONTROL

Each month, visually inspect the waste pile through the waste access door. If the pile seems dry, especially towards the front (near the door), then water the pile for about 5 minutes with a hose having a spray nozzle. Repeat this daily until water appears in the liquid end-product chamber at the very front of the tank's bottom. If the pile seems too wet, add extra bulking agent each week until the pile seems moist and crumbly, and work it into the pile with a rake. Review usage for potential overuse and control access, if necessary.

III. VENTILATION

Every month check the draft by holding a blown-out match near the edge of the toilet seat while lifting the lid slightly. The smoke should be drawn into the toilet. If not, check the fan or clean the vent stack. Also check for debris or insect buildup in screen. If the "Purdue" air flow scheme is used this procedure will need minor modification.

Check the ventilation further by holding a blown-out match near the air inlets on the end-product access door on the front of the tank. If the smoke does not enter the tank, open the end-product access door and check to see if liquid or compost is blocking the triangular air duct openings in the front baffle. If so, clean the openings.

IV. REMOVAL OF LIQUID AND COMPOST

If liquid is drained or pumped automatically to a leach line or to a greywater system, there will be no maintenance other than keeping the drain line clear and the pump operational.

Under no circumstances should the liquid be allowed to accumulate high enough to cover the air intakes in the end-product chamber. If liquid level rises, unclog screen in liquid baffle.

Twice a year, check the end-product chamber for accumulation of compost. Always leave approximately a 10-in. layer on the bottom. About 2 bushels will have to be removed after the first year, during which no end product will appear.

6 in. above the vault bottom. More sophisticated distributors have been tried, but the concentrated wastes tend to clog them.

This system requires no daily maintenance, and no chemicals or additives are needed. However, the aeration system is a mechanical device, and requires some minimum service. Weekly checks are recommended to assure continued system operation. No lubrication is needed if a carbon vane blower is used. The only maintenance required is changing the vanes and bearings every other year (a 2-hour job). The drive belt should be adjusted every other month and changed twice each year. An air filter on the blower requires cleaning or changing twice a year (more often in dusty areas). A motor with permanently lubricated bearings should operate continuously for 5 years without maintenance. Each time the vault is emptied, clean water should be added to just cover the air distribution pipe for system startup, approximately 8 in. of water (see Figure 4).

Total material costs for the motor/blower unit are about $600 (1984 prices), and it takes about 50 hours of skilled labor to fabricate. The motor/blower units can be manufactured locally or purchased. One source is Lewis Chemical & Equipment Co., Inc., with prices in the $1500 range (discounts available with quantity purchases). The piping network fabrication and complete installation can be done by DEH plumbers and electricians in about 12 man-hours per unit. Experience will reduce the amount of labor required. Complete retrofits (i.e., addition of motor/blower unit, piping network, etc.) will cost less than $2000. When used with new construction, the cost will be $14,000 to $17,000 for a unit that can meet the needs of personnel for one firing range (i.e., six to eight stools plus associated urinals). Based on $0.10/kWh, power will cost $480 per year. The latrines will still require pumping as needed, but evaporation will increase volume loss, thereby requiring fewer annual pumpouts.

Although this system does not treat the wastes completely (periodic pumpout is still required), it significantly reduces oxygen demand, which reduces the load on the treatment plant when the vaults are emptied, and is much easier to pump as a more homogeneous material. This, along with the vastly improved aesthetics and reduced pumping requirements it provides, makes vault aeration the most viable alternative for remote site waste management where existing latrines are in repairable condition and electric power is available. They are also excellent options for new construction.

Cycling of the blowers has been tried but is not recommended. Solids buildup may shift air to other holes making cleaning of the pipes necessary. Also, the energy saved is not that much compared with the stress on the motor/blower unit from switching on and off.

Selection of the most appropriate remote site waste treatment technology requires data on number of users on a daily, seasonal, and annual basis; climate considerations; length of service time required; availability of roads and utilities; environmental considerations; and economics. An analysis should be performed at every location. The assumption remains that water is unavailable for waste disposal, thereby precluding use of septic systems and various package plant alternatives and conventional sewage disposal alternatives.

Chapter 4 and Appendix C provide details on the design of aerated vault latrines. Vault latrines have many standard designs which can easily be retrofitted with vault aeration units. Important considerations include having easy access to the pumpout location, ensuring proper ventilation of building and vault, and using good-quality, heavy-duty components in the motor/blower unit.

Technology Recommendations

Analysis of information on currently available technology indicates the following applications:

1. Use of chemical latrines for short-term or temporary service

2. Use of aerated vaults for new construction sites with electricity and roads

3. Use of composting latrines with a solar package for sites where trucks cannot reach the units easily and electricity is unavailable

4. Use of aeration units for upgrading existing vault latrines in rehabilitatable conditions

5. Phasing out of pit latrines at major use sites.

Table 3 presents cost data for a typical firing range under normal use. It is assumed that: service is for one company per day and that the pit, vault, and aerated vault

Table 3

Costs of Waste Treatment Service for Typical Firing Range*
(Normal Use—1 Company Per Day)

	Pit Latrine	Unaerated Vault Latrine	Chemical Latrine	Aerated Vault Latrine	Compost Latrine
Initial Cost ($)	10,000	12,000 to 15,000	None	New construction of vault latrine 14,000 to 17,000	60,000-70,000 Retrofit--2,000
Annual O&M ($)	640	900	3,600	1,230	700
Total Annual Cost ($)	1,580	2,320	3,600	New construction of vault latrine 2,910 Retrofit of existing vault latrine 1,490	7,310

*Labor costs are assumed to be $10 per hour and the price of electricity to be $0.10/kWh; costs assume a 20-year life, except for a 5-year life on the motor/blower unit used for vault aeration, and a 7 percent discount rate. All systems are assumed to be equivalent in their abilities to handle one company of troops.

latrines consist of a building with six to eight seats and urinals. The compost latrine setup includes one building with three of the largest sized tanks, six seats, and urinals. Six chemical latrines are used. This number represents the situation at typical firing ranges, although Army guidelines indicate that more chemical latrines should be used. When coupled with inflation rates, the high annual operations and maintenance (O&M) costs for chemical latrines will balloon quickly. For example, under the given conditions, in 20 years, it will cost more than $13,000 annually to service these six chemical latrines. The table also shows that the status quo is the least-cost alternative; however, this alternative is unacceptable in terms of user satisfaction, aesthetics, and environmental concern. Aerated vaults show a substantial economic advantage over chemical latrines and composting latrines.

4 AERATED VAULT LATRINES

The Army currently owns hundreds of unaerated vault latrines, most of which are located on remote training ranges. These consist of a simple wood frame or corrugated metal building containing six to eight toilets and two to four urinals located over an open concrete tank or vault. The vault, usually about 1500 gal in volume, holds the wastes only until they can be pumped and taken to a treatment plant for proper disposal.

The problems generally associated with vault latrines are unpleasant odors, unsanitary conditions, vector problems such as flies and mosquitoes, and high pumping costs. Most of these problems occur because the wastes are allowed to decompose anaerobically (i.e., they are not kept in contact with air). Oxygen-starved (anaerobic) wastes will support the growth of bacteria that produce odor-causing end products (e.g., methane, hydrogen sulfide, and mercaptans). Coliform and other disease-related bacteria thrive in an anaerobic environment, and flies and other vectors can feed and reproduce on the stagnant, often crusted, surface. Although anaerobic decay does reduce waste volume, it is a relatively slow process.

By maintaining the wastes in a vault in a mixed aerated environment, most of the problems associated with vault latrines can theoretically be eliminated. Aerobic bacteria will be favored; these produce end products of carbon dioxide and water vapor, thus reducing odors. Flies and other insects cannot breed on a turbulent surface, so vectors are greatly reduced. Finally, aerobic decomposition proceeds more quickly than anaerobic decay.

Although this system does not treat the wastes completely (periodic pumpout is still required), it significantly reduces oxygen demand, which reduces the load on the treatment plant when the vaults are emptied. This, along with the improved aesthetics and reduced pumping requirements it provides (increased evaporation should produce one or two fewer pumpouts per year), makes vault aeration a viable alternative for remote site waste management where existing latrines are in repairable condition and power is available, as well as in new construction.

Pit latrines and unaerated vault latrines will continue to be used on military installations until upgrade measures are implemented. Therefore, to keep them in top operating condition, it is recommended that users refer to Appendix C, *Vault Toilets: Design and Maintenance Considerations*. More information is available from a U.S. Forest Service publication, *Updated Vault Toilet Concepts*, which can be obtained from the USDA Forest Service Recreation Department in Washington, DC.

Aerated Vault Design Criteria

The Army Corps of Engineers' Fort Worth District has been using aerated vault latrines since 1974 at Ben Brook Reservoir recreation area. They have worked with various types of air compressors and blowers, and tried a number of diffuser types before developing the system they now use. This system consists of a lubrication-free, carbon-vaned blower which is belt-driven by a permanently lubricated motor. The blower's inlet is fitted with a replaceable-element air filter, and the outlet connects to a perforated air distribution pipe mounted approximately 6 in. above the vault floor. Air continuously supplied by this system mixes the wastes and supplies oxygen to them. The Corps has used this system successfully on a number of their vault latrines since 1975. USA-CERL

has visited these systems in operation and has subsequently adapted them for use on Army latrines (see Figure 4 and Figures 9 through 13). The following design calculations were used to arrive at the proper size unit for a given application. Given:

75 troops training fulltime (16 hr training and 8 hr sleep each 24-hr period)

(120 g feces and 1.1 L urine)/troop/24-hr day

BOD_5: 10 g for 100 g feces, and 10 g for 1 L urine

1 kg O_2/kWh of blower output

6 g O_2/m^3 air per meter of diffuser depth (transfer efficiency)

2 kg O_2/kg BOD_5 required

Daily Loading:

75 troops x (120 g feces and 1.1 L urine per troop per day) x

(10 g BOD_5 per 100 g feces and 10 g BOD_5 per L urine)

= 1725 g BOD_5, or 1.73 kg BOD_5.

Assume average vault depth of 1 m.

$[(1725 \text{ g } BOD_5/24 \text{ hr})/(6 \text{ g } O_2/m^3 \text{ air})] \times (2 \text{ g } O_2/\text{g } BOD_5)$

$= 575 \text{ m}^3 \text{ air}/24 \text{ hr}$

$= 0.4 \text{ m}^3 \text{ air/min}$

= 14.1 cfm.

Power Requirement:

$1.73 \text{ kg } BOD_5 \times 2 \text{ kg } O_2/\text{kg } BOD_5 = 3.5 \text{ kg } O_2/24 \text{ hr}$

$= 0.14 \text{ kg } O_2/\text{hr}$.

Since 1 kg O_2 is produced for each kWh blower output, 0.14 kW are required.

$0.14/(0.5 \text{ eff}_{motor}) \times (0.8 \text{ eff}_{drive}) (0.7 \text{ eff}_{blower})$

= 0.5 kW electrical power required.

0.5 kW x 1.34 hp/kW

= 0.67 hp.

Thus, a 3/4-hp motor is required.

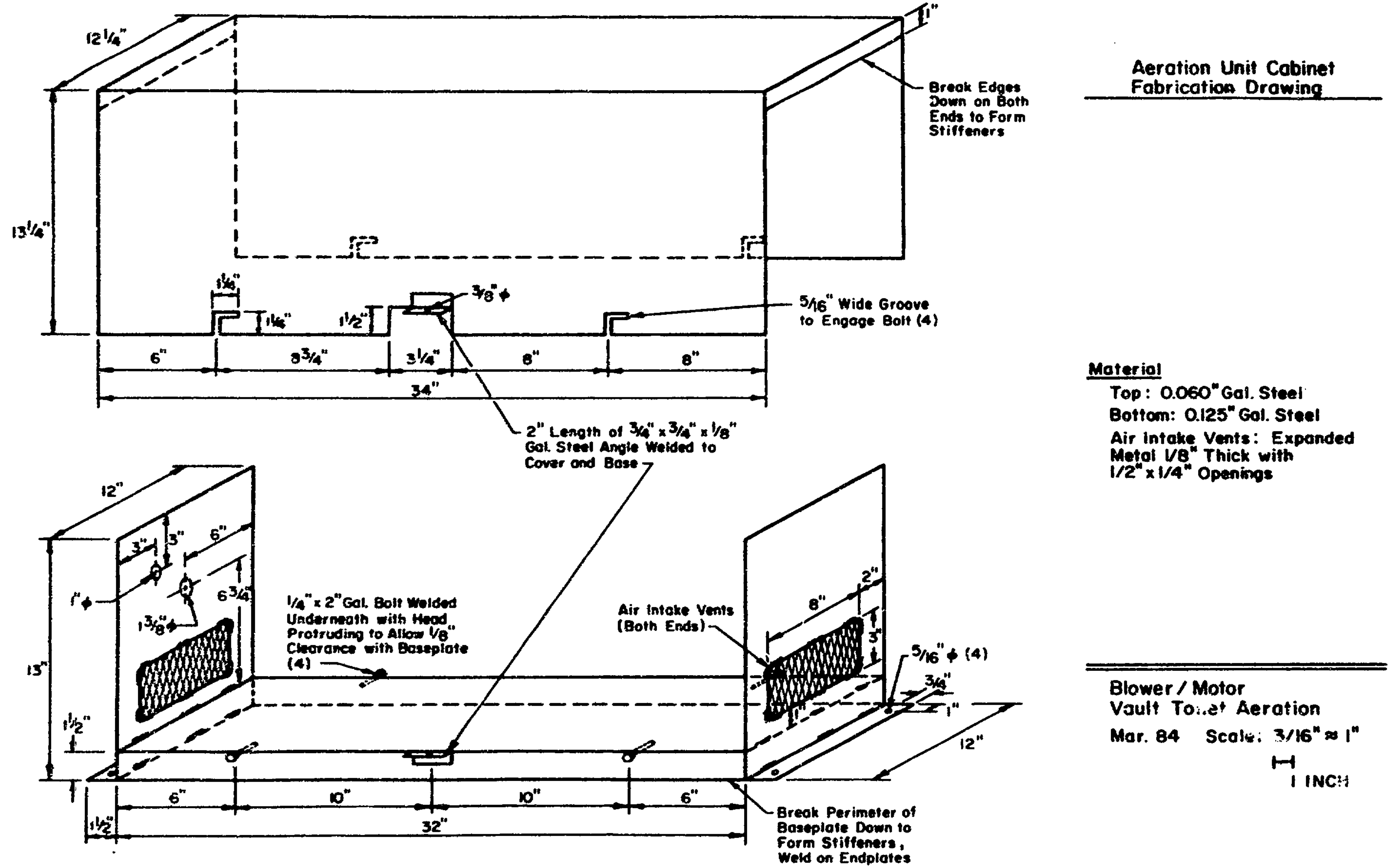


Figure 9. Aeration unit cabinet fabrication drawing.

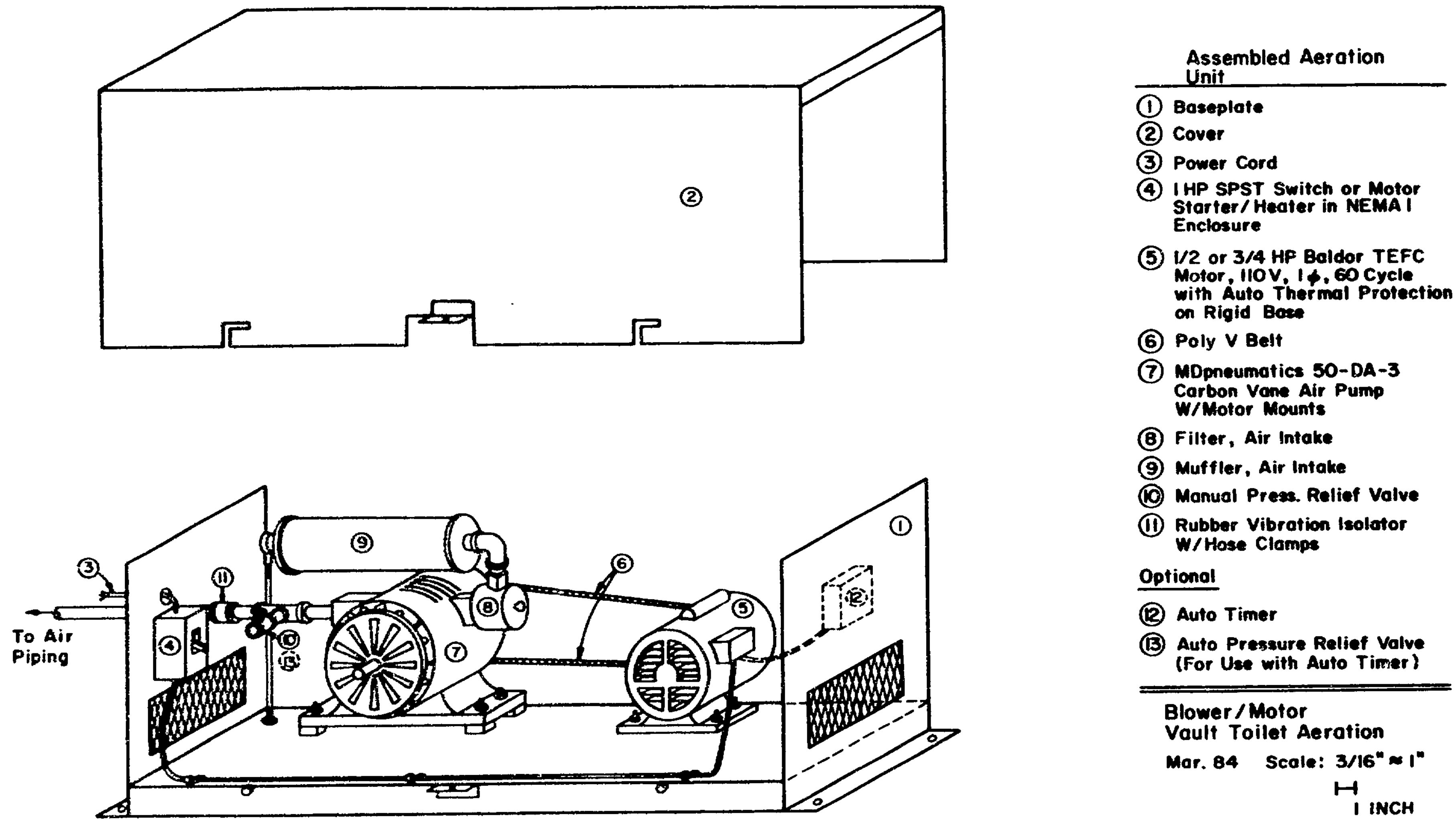


Figure 10. Assembled aeration unit.

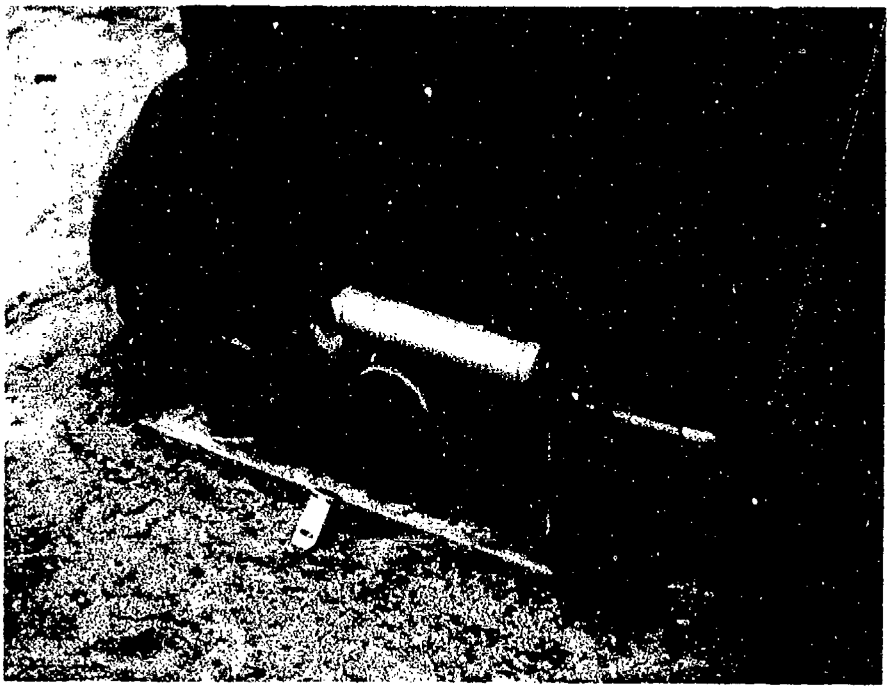


Figure 11. Motor/blower unit.

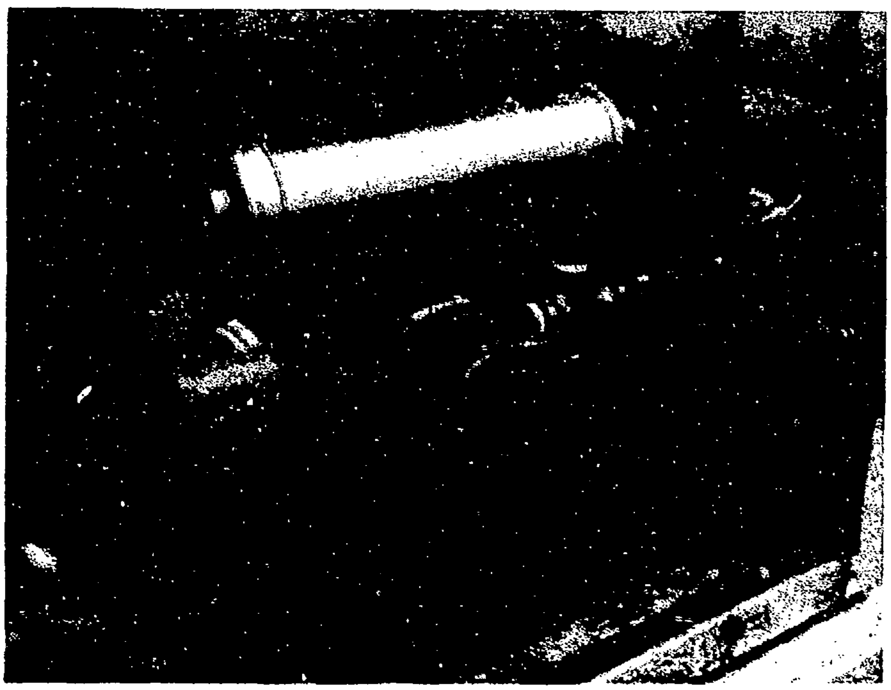


Figure 12. Motor/blower unit (enlarged).

Figure 13. Aeration unit installed.

Field Installations

Installation and Components

USA-CERL built seven motor/blower units based on the calculations given above and installed them on Army latrines (one at Fort Leonard Wood, MO, one at Fort Dix, NJ, and five at Fort Jackson, SC). Each latrine was retrofitted with an aeration pipe that was then connected to the motor/blower unit. Once the systems were installed, water was pumped into the vaults to cover the air pipe by about 6 in. for startup.

This system was easy to build and install. The only drawback to installing it was that the vault had to be completely cleaned, since personnel had to enter it to anchor the air pipe. Later installations dispensed with complete cleanout of the vault, using only a thorough pumping, and installers did not enter the vault.

The bubble aeration system was built around an M-D Pneumatics, Inc., dry air pump. This unit was chosen because of its carbon vanes and sealed bearings, which means that no lubrication is required. The manufacturer claims that the only required maintenance is replacement of the pump vanes every 2 years. A permanently lubricated motor and belt drive were also chosen to minimize maintenance requirements. An air filter was placed on the pump intake to reduce pump wear caused by abrasive particles. Although this is a maintenance item, it should reduce overall maintenance time requirements because the pump vane life will be increased. The pump outlet was attached to perforated PVC pipe which is mounted 6 in. off the floor of the vault along its length. The motor/pump unit was housed in a locked metal box for protection from the weather and from tampering.

Prior to installation of the retrofit apparatus, the vaults require a thorough pumping. Following this, a 6- to 8-in. layer of water is added to cover the horizontal piping. For optimal operation, no chemicals should be added.

The general construction process for the piping network uses 3/4-in. PVC. Generally, two 10-ft lengths are cut as needed: one for the horizontal distance along the bottom of the vault and the other for the riser section. Three-fourths-inch cast iron pipe is used for leg supports to keep the perforated section above the vault bottom and out of the sludge which may be present. Cast iron pipe is also used for aboveground connections to avoid vandalism. Electrical connections follow acceptable practice. Appendix D provides a more detailed typical construction plan and list of materials.

Field Observations

The aerated vault latrines were consistently odor-free and produced a relatively low BOD throughout the sampling period. In general, the aeration system appeared to be totally adequate for keeping the unit aerobic and for producing a well-mixed system. Proper placement of the aeration pipe is important. In two latrines at Fort Jackson, the aeration pipe entered the vault vertically, about 1 ft from the wall, and then turned horizontally to span the remainder of the vault. In these two aerated latrines, a stagnant region with a scum layer was present along the wall where the aeration pipe entered the vault. In each of the other aerated latrines, the aeration pipe entered the tank adjacent to the vault wall and the entire vault was well mixed. Thus, mixing was best when the pipe was installed along the wall.

The aeration equipment has performed without problems, except for one unit at Fort Jackson, where the blower was not functioning. When the blower was repaired, the unit became a well mixed, aerobic, odor-free, user-acceptable unit within 1 week.

It was also noted that users unanimously preferred aerated units to unaerated ones, as indicated by verbal comments, the care taken to keep these units clean, and evidence that they were used more frequently.

Unaerated units were also monitored intensively at Fort Jackson. The men's unit had very few suspended solids. Two women's units--one functional and one non-functional--both had scum layers about 1 in. thick on top. These scum layers kept the newest feces from being degraded rapidly by holding them above the main body of wastewater. This provided a fertile breeding ground for maggots, helminths, and possibly pathogens.

Laboratory research was performed to evaluate the processes occurring during latrine aeration. Appendix E presents results of that research, which confirm significant reductions in organic strength of the waste and show that odors can be controlled. Optimization studies indicated that continuous operation provides the best treatment and odor control.

Costs

The units can be purchased directly for $1100 to $1900 per unit, depending on quantity ordered. They can also be constructed locally by the DEH or local machine shop or similar contractor. With a pre-built motor/blower assembly, installation took less than two man-days (12 hr) per unit. Mass production or more installation experience will reduce the amount of labor required for this work, which includes construction of the piping network, plumbing, and electrical work and light carpentry as needed to access the

vault. Each unit requires a specific plan dependent on site-specific conditions. Based on energy costs of $0.10/kWh, power will cost $480 per year. This system, when installed on a latrine having six to eight stools and two urinals, will support the needs of 100 or more persons on a fulltime annual basis.

Total retrofit capital costs, assuming a pre-built motor/blower unit and $15 per hour for labor and about $200 for miscellaneous hardware, are about $2000 per unit. Figures 11 and 12 show a more detailed plan of the motor/blower assembly. The USA-CERL installations have all been on concrete blocks or pads outside the latrine building. Fort Worth District units have been placed in raceways and on top of flat concrete slab roofs. However, their buildings are of a higher-cost level of construction than most firing ranges and bivouac areas.

5 COMPOSTING LATRINES

Design

Composting latrines appear to offer several advantages:

- Self-contained operation
- Low maintenance requirements
- Enhanced aesthetic qualities
- Relatively simple construction and installation.

Although the concept of composting latrine design dates back several decades, the associated technology must still be considered an emerging science. To a great extent, contemporary composting latrine systems are designed and operated according to empirical criteria based on previously successful field applications.

Figures 14 and 15 show the design configuration used for a representative composting latrine system. The system illustrated here is manufactured by Clivus Multrum;

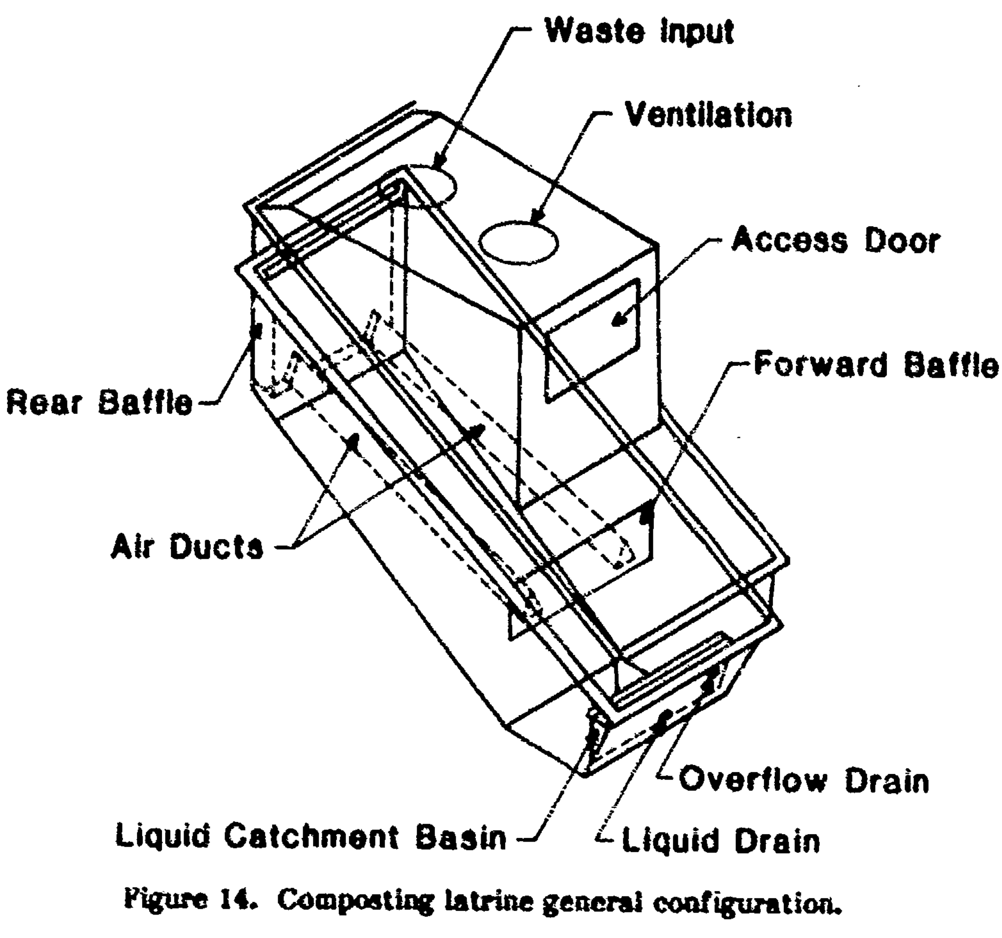


Figure 14. Composting latrine general configuration.

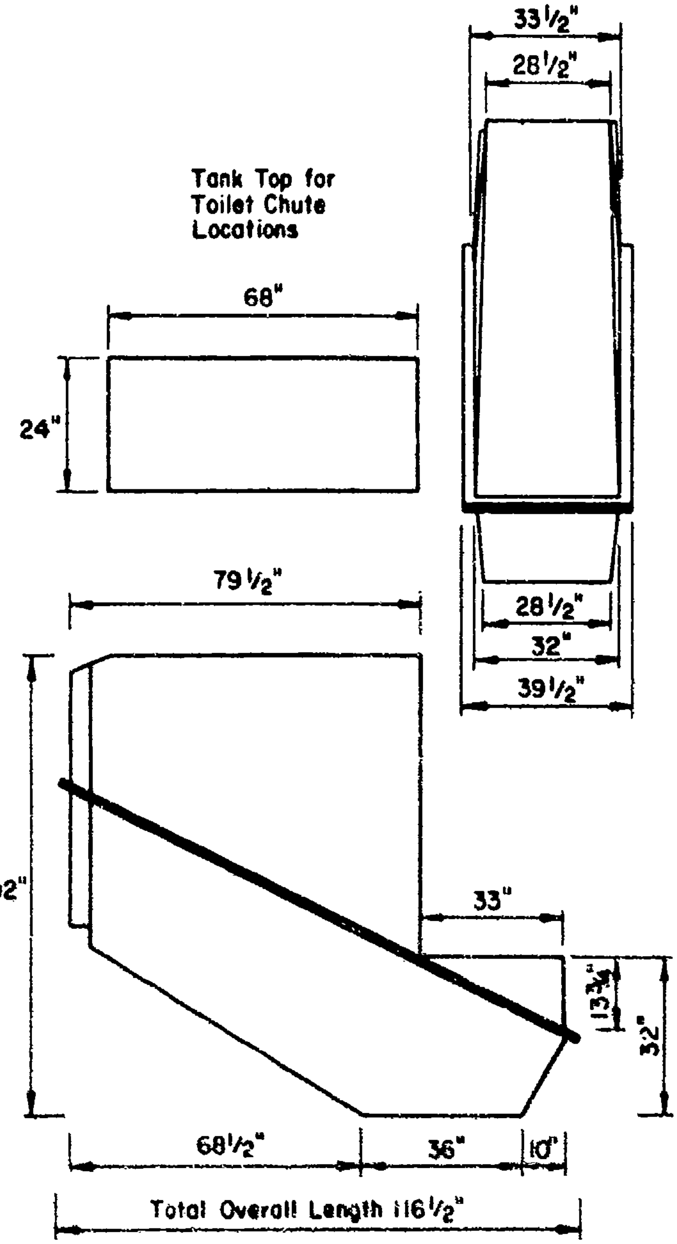


Figure 15. Schematic of composting latrines.
(Source: *Public Facilities Planning Manual*
[Clivus Multrum, Inc., August 1986].)

composting latrines are also manufactured by the Compost Toilet System Company. The products of both companies are similar. However, Clivus Multrum is a larger and older organization, which may merit consideration for troubleshooting and followup service. A composting latrine is more than a holding vault for deposited liquid and solid wastes; it is typically configured to mechanically aerate the collected wastes. Waste treatment is by degradative changes in both the character and volume of the contained residue. These changes result from a combination of physio-chemical and biochemical mechanisms occurring within the latrine, including evaporative moisture loss and microbial metabolism. Composted residue taken after several years from optimally operating units has been documented as an innocuous solid product that can be useful as a soil

stabilizer.[2] However, there is very little documentation available; most analyses deal with indicator organisms.

The relative importance of the treatment mechanisms (evaporative moisture loss versus true biological treatment) has not been firmly established. On the one hand, waste volume reductions may result largely from moisture losses induced by pile ventilation. On the other hand, microbial degradation of waste constituents may play a significant and complementary role in degrading the waste materials.[3] Thus, these composting latrines might be viewed as "black boxes" that tend to convert objectionable waste materials into an innocuous product.

The means to this end would not be of concern if the desired composting process were attained consistently. However, as reflected by process failures (and witnessed first-hand by the authors in Army applications), composting latrines can have operational difficulties. Consequently, research was begun to critically and technically evaluate the physical, chemical, and biological behavior of a functional composting latrine.

The composting latrine process is a generic waste treatment scheme that has been applied under a variety of commercial and "do-it-yourself" or "site-built" approaches. This technology first became commercially available in the late 1930s, eventually leading to proprietary sales of the Clivus Multrum model throughout Europe, Canada, and the United States.

Several additional commercial models have since been brought into this market. These commercial models may be roughly subdivided into large units intended for continuous use and smaller units for intermittent or batchwise applications. For most Army applications, only large units are appropriate.

The "site-built" systems are usually less sophisticated in both design and construction material. While a commercial model will probably employ a complex, prefabricated, fiberglass shell, "site-built" systems range from plywood boxes to simple hand-dug pits. Many publications document appropriate design, construction, and application of these "site-built" systems in less developed countries. A recently published "Planner's Guide" for composting latrine use[4] provided a brief overview of 11 different types of onsite, appropriate-technology wastewater treatment systems and a related set of literature citations.

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[2]Personal communications with M. Bjorklund (Wild Life Prairie Park, Peoria, IL, May 1983); L. DeJounge, "The Toa-Throne - A New Compost Toilet," *Compost Science*, Vol 17, No. 4 (September-October 1976), pp 16-17; A. Fields and D. Del Portino, *Organic Waste Treatment Systems (Composting Toilets): A Viable Alternative* (ECOS, Inc., 1977); M. Fogel, *Chemical Analysis of Clivus Multrum Compost*, information provided to Clivus Multrum (February 1977), pp 1-9; S. B. Hornick, L. J. Sikora, S. B. Sterrett, J. J. Murray, P. D. Millner, W. D. Burge, D. Colacicco, J. F. Para, R. L. Chane, and G. B. Wilson, "Utilization of Sewage Sludge Compost as a Soil Conditioner and Fertilizer for Plant Growth," *Bulletin No. 464* (U.S. Department of Agriculture, August 1984) pp 1-32.

[3]"The Toa-Throne - A New Compost Toilet"; C. G. Golueke, "Composting: A Review of Rationale, Principles and Public Health," *Compost Science*, Vol 17, No. 3 (Summer 1976), pp 11-15.

[4]J. B. Bruce, *A Planner's Guide to Composting Toilets for Low-Cost Shelter Development Projects*, Master's Thesis (Florida A&M University, 1983).

The multrum-type design is unique in that it incorporates semicircular or chevron-shaped ventilating pipes passing through the bulk of the contained waste. This feature likely helps improve ventilation within the compost pile. This design scheme also improves residual liquid drainage from the vault by inclining the tank bed toward the outlet end. (The "clivus" nomenclature was reportedly derived from the Latin for "sloping."[5]) Finally, this system's placement of hinged ports on the top and on the drainage end of the latrine facilitates expedient and convenient access to the latrine's interior, thereby improving routine maintenance activities such as bulking material input, liquid drainage, and manual pile raking.

Operational Concepts

Figure 16 illustrates the physical, chemical, and biological factors believed to have an impact on the multrum-type composting latrine performance. Overall, the interior of a composting latrine must be considered as a complex, dynamic ecosystem. This characterization greatly transcends the common perception of a composting latrine as a primitive waste management system.

The "ideal" composting latrine apparently involves a combination of physiochemical and biochemical treatment mechanisms. Ventilation certainly plays a major role, both for its effect on evaporation of input moisture and on the transport of substrate oxygen into the pile.

The pile conformation should facilitate movement of the oxygen throughout, with an appropriate degree of channeling and voids within the contained solids. Bulking materials such as wood shavings or sawdust, are often added to improve the pile's permeability to gas, as well as to provide additional carbonaceous substrate material to balance the nitrogen-rich wastes.

Oxygen brought into the pile will facilitate aerobic bacterial metabolism. Aerobic activity is preferable to anaerobic treatment because the latter produces noxious gases. Furthermore, aerobic degradation would greatly reduce the original waste volume.

The exothermic effect of these aerobic reactions may also increase the temperature within the pile, with a corresponding shift in the active microbial population (mesophilic to thermophilic organisms). Elevated pile temperatures could have an important and beneficial impact on pathogen survival and enzyme-catalyzed anabolism. Several authors have reported that temperatures in excess of 40°C will be obtained in all varieties of functional composting latrines including bin composters and the multrum-type units.[6]

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[5]L. D. Hills, "The Clivus Toilet - Sanitation Without Pollution," *Compost Science* (JG Press, May/June 1972), pp 8-11.

[6]D. Del Portino, "What's in the Future for Composting Toilets," *Compost Science* (JG Press, August 1977), pp 16-17; Stephen C. Fay and Raymond E. Leonard, "Composting Privy Wastes at Recreation Sites," *Compost Science* (JG Press, January/February 1979), pp 36-39; D. Felton, *State-of-the-Art Assessment of Compost Toilets and Greywater Treatment Systems* (The Winthrop Rockefeller Foundation, 1981); A. Fields and D. Del Portino, *Organic Waste Treatment Systems (Composting Toilets): A Viable Alternative* (ECOS, Inc., 1977); L. D. Hills; H. H. Huntzinger, Memorandum: Subject-Clivus-Multrum Data, Includes Technical Report by P. Bednorz (U.S. Department of the Interior, 1983).

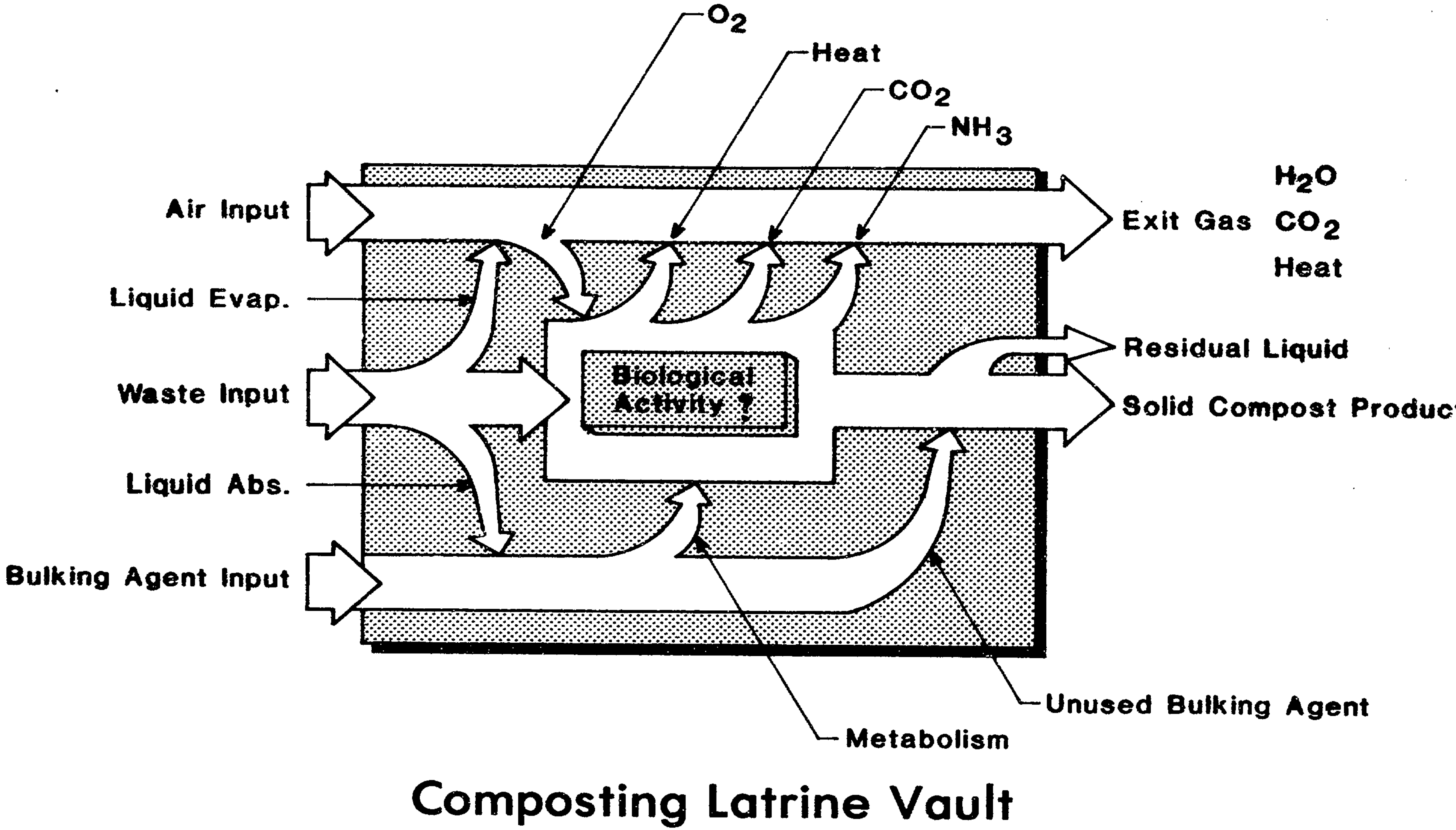

Figure 16. Composting latrine mass-balance schematic.

The occurrence and importance of this temperature buildup within a composting latrine is subject to debate. Operational data reported for several fullscale continuous composting latrine systems has frequently shown little indication of a temperature buildup,[7] and the demonstration Army field units have confirmed this. Bin composters have reached temperatures capable of killing pathogens, but are inappropriate for the Army because of their intensive operation and maintenance requirements. After extensive testing, it is clear that temperatures reached in large composting latrines are only minimally above ambient conditions. This lower temperature biological decomposition relies on unfavorable conditions and time to provide for destruction of pathogenic organisms.

The critical "balance" associated with this system is reflected in the effect ventilation has on both the physiochemical and biological mechanisms. For example, excessive ventilation will likely ensure the availability of oxygen within the pile, but may produce some solids dewatering, which inhibits optimal bacterial performance. Secondarily, elevated ventilation rates might negate the possibility of a temperature increase within the pile and its related benefits.

At the other extreme, insufficient ventilation could have even more serious ramifications. Decreased moisture loss from the pile would cause fluid buildup within the solids matrix (i.e., within the channels and voids). This buildup might subsequently block gas permeability throughout the pile. In turn, the desirable aerobic environment would be replaced with the undesirable anaerobic activity. Necessary reductions in the volume of the composting materials, including both the solid and liquid fractions, would drop substantially and severely reduce the latrine's functional longevity.

Several other variables with regard to "balanced" composting latrine performance must also be considered. Seasonal and/or external effects on the temperature of the composting pile will affect the rates of microbial activity and moisture evaporation. The humidity and temperature of the influent gas stream will affect fluid evaporation from the pile. The character, frequency, and magnitude of waste input will certainly have substantial bearing on the latrine's performance. The maintenance procedures applied to the system (e.g., bulking material addition rates, type of bulking material, raking procedures, etc.) will also be quite important. Finally, the presence and activity of eucaryotic and invertebrate organisms within the pile may have a sizeable effect on its metabolic degradation.

Based on the system's complexity, the involved control parameters must be given particular attention. Three basic factors are involved:

1. Adjustments in the ventilation rate

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[7]Personal communications with M. Bjorklund (Wildlife Prairie Park, Peoria, IL, May 1983); "The Toa-Throne - A New Compost Toilet"; Letter to E. D. Smith (USA-CERL) from M. Fogel (March 1984); M. Fogel, *Evaluation of the Rate of Decomposition in a Clivus-Multrum Organic Waste Treatment System*, information provided to Clivus Multrum (undated); Dag Guttormsen, "Evaluation of Compost Toilets - A Field and Laboratory Update," NSF Sixth National Conference (1979), pp 147-153; Dag Guttormsen, "Some Aspects of Composting Toilets With Specific Reference to Their Function and Practical Applications in Norway," NSF Fourth National Conference (1977), pp 145-151.

2. Adjustments of the pile's composition and character using additions of bulking/substrate materials and pile raking

3. Regulation of the frequency and extent of waste loading.

The second procedure is likely to be the most significant standard control factor. Operating regulations imposed on the loading of the latrine would inherently restrict the intended use of the system. This approach would perhaps be more appropriate if a current or impending process failure required drastic corrective action. Adjustments in the ventilation rate and waste loading are more design-related factors than operational parameters.

Manually adjusting the character and composition of the pile will be a user's primary approach to controlling the composting latrine. These adjustments may include addition of bulking materials, carbonaceous substrates, nitrogenous substrates, and water, as well as physical agitation of the pile to promote its ventilation potential, thermal balance, and microbial distribution.

Admittedly, an unattended latrine (i.e., with zero operations and maintenance assistance) may haphazardly demonstrate satisfactory performance. However, this mode of operation could neither be recommended nor successful on a long-term basis. The following section examines various concerns for composting latrine operations. However, the system's health-related aspects alone justify the effort of providing operational assistance.

Operations Concerns

Systems Loading

The literature generally bases quotations for composting-toilet design loadings on annual user inputs. For example, the Clivus Multrum Model PF-103 (equipped with a 24-in. midsection spacer) has a recommended annual loading of 10,000 uses at 55°F and 18,000 uses at 65°F.[8]

The permissible loading for a given latrine depends on both the size of the receiving vault and the reduction attained in waste volume through evaporation and degradation. The Clivus Multrum PF-103 unit has an approximate volume of 109.5 cu ft within its composting zone. (Note: The manufacturer states that 93 cu ft are available for composting; the remaining volume would be head space.)[9]

The wet waste volume associated with 18,000 user inputs (based on 375 mL per use) would be about twice the composting latrine's vault volume (239 cu ft). Furthermore, the input waste volume would be increased by 8 to 15 percent in accordance with the addition of bulking materials, which Clivus Multrum recommends to be 1 to 2 cu ft per 1000 uses. However, these loading figures should also be examined as dry waste volumes based on the system's expected moisture removal capability. In this case, the combined annual user and bulking volumes would amount to 43 cu ft. This volume is consequently less

[8]*Specifications: Planning Information for a Public Facility* (Clivus Multrum USA, Inc., April 1983a).
[9]*Planning, Installation and Operation Manual for Public Facilities* (Clivus Multrum USA, Inc., June 1983c).

than half that of the Clivus Multrum's composting vault volume. Biological degradation of these materials would also tend to further reduce this volume.

The characteristics of the waste itself also affect this calculation due to variations in volume reductions for liquid and solid wastes. Appendix J addresses input waste characterization. In the case of a predominantly liquid input, the permissible loading would be determined primarily by the degree of moisture removal achieved either through evaporation or direct drainage.

Evaporation would be preferable to direct drainage of liquid given the system's intended use for waste "treatment" rather than temporary storage. If direct drainage is anticipated to be a major pathway for liquid removal, it might actually be preferable to selectively direct (i.e., using urinals) most of this liquid waste into the necessary drainage/leach field without complicating operation of the composting latrine. This practice would appear to be useful in systems designed for natural ventilation or where the forced ventilation simply cannot match the evaporative demands of the incoming liquid volume.

System Aeration

The available literature on composting latrine design and operation provides virtually no technical information on the required ventilation flow. Design articles normally discuss the diameter of the ventilating outlet pipe and the particular configuration of the "plumbing" needed for pile aeration rather than necessary airflow levels.

Available documentation on Clivus Multrum systems generally references the installation of 6-in.-diameter outlet pipe with an in-line fan rated at 2.85 to 3.25 m^3 min^{-1}.[10] The operational air flow rates through such a system, which encompasses inevitable head losses through the pile and "plumbing," are reportedly about 0.57 m^3 min^{-1}.[11]

Felton[12] indicates that a ventilating gas flow velocity of 300 mm^3 hr^{-1} $gram^{-1}$ would be required. (Note: This citation does not clearly specify what the "gram" measurement refers to--whether it is for grams of incoming waste or grams of pile material in place.) It is likely that this rate was based on total solids within the vault. However, even in this case, the corresponding ventilation requirement for a Clivus-Multrum-sized system would only be 0.03 m^3 min^{-1} (obviously an erroneous value).

This shortage of technical information on airflow rates and distribution patterns appears somewhat unusual given the parameter's apparent significance. Variations observed in the performance of the assorted commercial composting latrines may well be attributed to related changes, particularly in comparing forced ventilation units with those designed for natural airflow.

For designs that include forced ventilation, the gas flow rate should probably be linked with the size of the latrine vault according to a gas flow rate per unit volume factor. Based solely on the approximate 0.57 to 3.25 m^3 min^{-1} flow rate identified for the Clivus Multrum unit and its expected pile volume of about 2.6 m^3, an approximate

[10] *Planning, Installation and Operation Manual for Public Facilities.*

[11] *Planning, Installation and Operation Manual for Public Facilities; Specifications: Planning Information for a Public Facility.*

[12] D. Felton.

ventilation throughput of 1.23 $m^3 min^{-1}$ per cubic meter of vault pile volume may be used as a tentative starting point for ventilation design.

Input Gas Temperature and Humidity

Despite the available ventilation rates and pathways, ambient atmospheric conditions will greatly affect moisture evaporation and heat dissipation from the pile. Increased inflow gas temperatures and decreased relative humidities will both promote evaporative moisture losses. Conversely, heat loss from the pile will increase in relation to lower input gas temperatures and higher humidity levels.

Guttormsen[13] prepared an approximation of moisture removal from a composting latrine using the following system characteristics:

- Ventilation gas flow = 0.42 $m^3 min^{-1}$
- Inlet gas temperature = 20°C
- Inlet gas humidity = 40 percent
- Outlet gas temperature = 25°C
- Outlet gas humidity = 60 percent

According to this analysis, 4200 mL would be removed from the latrine each day (basically equivalent to 10 L of liquid evaporated for each 1 $m^3 min^{-1}$ of ventilating gas flow).

In accordance with the 3.25 $m^3 min^{-1}$ ventilation figure given for a standard Clivus Multrum, the corresponding total daily moisture loss of 32.5 L would equate to a permissible daily waste input by about 22 users (assuming a 1.5-L volumetric decrease between the wet and dry waste phases) and an annual total of about 8000 uses.

This value is less than half the loading rate recommended in the Clivus Multrum technical literature. However, it is possible that the actual operating temperature and humidity differences might yield a liquid removal rate equivalent to a higher user loading level.

Overall, the 10 L day^{-1} moisture removal per 1 $m^3 min^{-1}$ ventilation rate correlation probably represents a reasonable starting point for determining design gas flow rates. However, site-specific environmental conditions (temperature, humidity, etc.), user waste characteristics, and loading rates must be considered in this evaluation.

For example, a predominantly liquid input would probably not allow for a similar temperature increase between the inlet and the outlet gas streams due to a specific reduction (per unit pile volume) in heat released through microbial activity. In this case, the applied ventilation rates would have to be increased.

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[13] Dag Guttormsen, "Evaluation of Compost Toilets - A Field and Laboratory Update."

Residual Liquid

The presence of residual liquids in a composting latrine will depend on a relative mass transfer situation. Several citations have indicated that a maximum theoretical residual of 250 mL per use (an average use) can be expected.[14] This would be a sizeable segment (i.e., about 60 to 70 percent) of the liquid fraction for each user's input. However, in at least one instance, a full-scale set of composting latrines was maintained for several years without any routine residual.[15] Again, site-specific variations in loading patterns, environmental conditions, ventilation rates, etc., will greatly affect process performance.

In the case of the Clivus Multrum system (250 mL residual per use), it appears that the ventilation rate should be increased. Indeed, this process apparently "treats" or "composts" only one third of its input load; the remaining volume must be drained into a subsequent liquid disposal system. Clivus Multrum estimates about 225 mL liquid per day will be produced requiring liquid disposal. The liquid is generally low in pathogens.

Ventilation effects will primarily control the occurrence and extent of residual liquid discharge from the pile. Evaporative losses which equal or exceed the liquid input will negate this problem. However, if a residual is consistently discharged, a satisfactory disposal scheme must be arranged.

Composted Product Withdrawal

The frequency and quantity of product withdrawal from a composting latrine will depend on the site-specific performance of individual units. The literature and vendor-supplied documentation suggest that a composted product will not be ready for removal from a new unit for 18 to 24 months. Successive removals may then be made on either a 6- or 12-month schedule in proportion to the solids buildup noted.

The Clivus Multrum manual indicates that about 7.5 cu ft of composted product should be removed annually from the PF-103 model following its annual expected 18,000 uses. When considering the 43 cu ft of dry waste volume derived earlier, this withdrawal would correspond to an 83 percent reduction in the waste volume beyond moisture removal. By inference, this reduction would have to be obtained through biological degradation.

Physical Characteristics of the System

The recommended solids levels for the compost pile generally range between 40 and 70 percent with moisture content ranging from 30 to 60 percent. However, one long-term operator advocated a consistent 50-50 split on the solids-moisture percentages.[16]

Moisture control in the pile is important because of the effect this parameter has on solids ventilation and microbial activity. A composting pile must have an inherent porosity through which ventilating gases may be passed. An excessively high liquid

[14]Clivus-Multrum, USA, Advertising Literature.

[15]Personal communications with M. Bjorklund (Wildlife Prairie Park, Peoria, IL., May 1983).

[16]Personal communications with M. Bjorklund (Wild Life Prairie Park, Peoria, IL, May 1983).

percentage would retard this beneficial gas movement by filling the pile's interstitial voids and channels.

Occasional additions of rigid, granular wood chips or shavings to the pile may improve the problem of excess liquid. These materials tend to have an absorptive effect, resulting in immediate uptake of excess liquid from the channels and voids. Also, their physical conformation tends to open up the solids matrix, thereby improving its gas permeability.

Other additives, such as whole leaves and long grasses, will have an opposite effect. These materials tend to compress and mat down, further inhibiting gas transfer within the pile.

Additions of peat moss have often been noted in the literature. The benefit of this material appears to stem primarily from its absorptive properties. Interstitial gas passages may then be opened, which improves ventilation.

Clivus Multrum literature typically recommends adding 1 gal of bulking material per 100 uses, or 1 to 2 cu ft per 1000 uses. For the PF-103 model, this would amount to 0.05 to 0.11 m^3 per year, based on 18,000 annual uses. This would represent less than 10 percent of the dry waste volume associated with this same number of user waste additions.

The volatile percentage of the solids fraction would be expected to decrease as the compost chronologically progresses from the point of input to its eventual discharge. This reduction in volatile solids is an indicator parameter for gauging the extent of solids degradation.

Chemical Characteristics of the System

As indicated by the data given in Appendix J, liquid and waste fractions have markedly different carbon and nitrogen compositions. Whereas a fecal and waste paper material will have more of a balanced carbon-to-nitrogen (C/N) ratio, urine has a significantly greater nitrogen fraction. Thus it is rather common for carbon-rich substrates to be added to composting latrines to obtain a desirable C/N ratio. The preferred ratio for these systems is generally considered to be about 15:1 to 30:1.

Table 4 provides information on the C/N ratios for several potential bulking materials. Carbon-rich substrates above the 20:1 level are typically used to balance out the nitrogen fraction of raw wastes. Systems receiving a predominantly liquid input would have an even greater need for carbonaceous substrates--both to balance metabolic activity and to open up or bulk the existing solids.

For systems capable of maintaining aerobic bacterial activity, the expected pH of the pile would be near neutral (7.0) or slightly higher in relation to the buffering action of ammonium ions and amino acid. However, if anaerobic activity develops within micro- or macro-scale sites, the pH may drop below 7.0 with the production of weak acid fermentative products such as propionic acid. The occurrence of anaerobic activity would also be marked by unpleasant odors from gases such as hydrogen sulfide and methane.

Table 4

Carbon:Nitrogen Ratios
Potential Toilet Additives

(Information derived from D. Felton, *State-of-the-Art Assessment of Compost Toilets and Greywater Treatment Systems* [The Winthrop Rockefeller Foundation, 1981].)

Urine	<1.0
Mixed slaughterhouse wastes	2
Blood	3
Activated sludge	6
Feces	5 to 10
Young grass clippings	12
Cabbage & tomatoes	12
Onions & peppers	15
Average grass clippings	19
Seaweed	19
Raw garbage	25
Oat straw	48
Wheat straw	128
Rotted sawdust	208
Raw sawdust	511
Newspaper	Very High

Biological Characteristics of the System

Heterotrophic degradation of fecal wastes within a composting latrine, both by aerobic and anaerobic metabolism, will inevitably produce carbon dioxide. Use of carbon dioxide in the off-gas stream has been proposed as an indicator parameter for characterizing the extent of bacterial activity within the system. However, this procedure has received limited application.

Fogel[17] prepared a theoretical analysis of the off-gas carbon dioxide concentration; results indicated that the carbon dioxide increase between the inlet and outlet gas streams should amount to about 1000 ppm. An operator could occasionally monitor this change to assess the latrine's viability and performance.

Taking carbon dioxide measurements in the range of 1300 to 1400 ppm (ambient plus 1000 ppm) is neither inexpensive nor simple. Fogel presented a technique for composting toilet vent gas analysis based on the use of manual gas sampling pumps and CO_2-selective sensor tubes. However, the accuracy of this procedure is not satisfactory as concentrations were nearly identical to ambient. USA-CERL field studies confirmed this finding. Refinements in this procedure are needed to fully use this tool. This was accomplished and is detailed in the individual experiments or laboratory research.

[17] *Evaluation of the Rate of Decomposition in a Clivus-Multrum Organic Waste Treatment System.*

Aesthetic Factors

The aesthetic characteristics of a composting latrine will probably dictate each user's immediate satisfaction with the system. Although visual appearance will be affected by cleanliness of the latrine exterior, rather than of the darkened interior, the prevalence of nuisance insects will be a serious detraction. Thus, insect control would yield a double dividend by reducing disease vectors and improving aesthetic quality.

Odor control may represent the most important aesthetic factor. Proper ventilation will provide a substantial improvement. First, an airflow pattern must be established that draws air downward through the seat opening rather than in the reverse direction. Unfortunately, the expected temperature difference between the latrine zone and the elevated seat location will tend to create a draft in the wrong direction (i.e., through an upward movement of warmer air into the vault area). Thus, systems that use forced ventilation should improve odor control, as well as provide related benefits in pile oxygenation and moisture evaporation. An assurance of proper aeration will also facilitate necessary oxygen transfer into the pile, thereby avoiding odor problems associated with anaerobic bacterial activity. Appendix F provides the results of a laboratory research effort which focused on the physical, chemical, and biological behavior of a composting latrine process being considered for use at remote U.S. Army facilities. The experimental "near-full-scale" unit built for this study received an annual user loading of approximately 4400 uses, representing a "wet" waste load volume ($1.68\ m^3$) that was nearly three times the size of its actual compost pile volume ($0.65\ m^3$).

The physical, chemical, and biological performance of this system was considered fully satisfactory. Virtually no residual liquid was obtained, indicating proper ventilation of the pile and its resultant effect on evaporative moisture loss from the composting solids.

Although microbial activity was detected within the pile (based on the presence of total bacteria, total coliform, and fecal coliform populations), the carbon dioxide release rate was rather nominal. In turn, the relative contribution of bacterial metabolism to this latrine's operation was considered secondary to the major volume reduction achieved through straightforward liquid evaporation.

Overall, the use of composting latrines appears to be a reasonable approach to onsite waste treatment. However, particular attention should be given to using appropriate ventilation rates through these systems to avoid operational problems with residual liquid and subsequent complications with pile conditions that lead to anaerobic activity.

Pile Moisture

Moisture in the pile depends on urine loading, rate of air ventilation, and quantity and frequency of bulking agent addition. Under normal use and with daily addition of a bulking agent, many owners of composting latrines have to add moisture to the pile occasionally. On the other hand, Army installations may find excess liquid in the pile because of heavy urine loadings; increasing the ventilation rate or adding bulking agent may solve the problem. More bulking agent can be added daily, using a trial-and-error approach; also, the pile can be turned more often to increase moisture evaporation.

With high urine loadings, excess liquid flows to the liquid storage compartment; from here, it can be drained by gravity or pumped from the composting latrine. To avoid blocking air ducts in the pile, the liquid should not be allowed to accumulate. If blockage

occurs, increasing the fan's size or adding more bulking agent will not help, since air cannot enter the pile. Consequently, anaerobic decomposition will begin, and the unit will not perform as designed.

The excess liquid can be handled in two ways. It can be stored in a collection chamber and pumped out periodically for treatment elsewhere, or a subsurface adsorption system or a leaching field can be used to dispose of the liquid. A percolation test will indicate the soil's suitability for subsurface adsorption and the appropriate application rate. Table 5 can be used as a guide. For example, it suggests that soils having a percolation rate equal to or less than 1 in./60 min are unsuitable for a leaching system. A large Clivus Multrum unit produces up to 6 gal of liquid per 100 users according to the manufacturer. Three times that amount is assumed for Army applications. However, under the least desirable percolation condition (0.45 gpd/sq ft) assuming every linear foot of trench provides 3 sq ft of absorptive surface area, a 22-ft leaching trench would meet even the most severe Army needs.

A mound system can be used when the percolation rate indicates that the soil is unsuitable for subsurface disposal. Only a small amount of soil is needed for a 22-ft-long trench of the mound system; the associated cost should be less than $250. However, if the composting unit is below grade, the excess liquid may have to be pumped to the mound system.

Installation

Some excavation and foundation work may be required to install large composting latrines. A composting latrine unit can be seated on a wooden rack placed on a concrete pad or on several concrete paving blocks. The latrine can also be half buried in a tightly packed earth and sand bed.[18]

When filled to capacity, the large composting latrines are fairly heavy. For example, the largest unit (a Clivus Multrum with two midsections) weighs 3000 lb with waste and peat moss bed material. However, installing the large composting latrines at remote sites with different soil types and densities presents few problems, because the support area of the tank's floor is quite large (26 sq ft).

Cost estimates for the two methods of composting latrine support are:

1. Concrete pad with wooden rack:

   48 hours of labor @ $14/hr $672

   Excavation, material $120

   Total $792

2. Partially buried on tight soil and sand layer with two concrete block retaining walls:

   Labor and excavation together $594

[18] *Planning, Installation, and Operation Manual for Public Facilities.*

Table 5

Sewage Application Rates
(Note: The Facilities Engineer should follow state and local regulations.)

Time for Water To Fall 1 in.	Allowable Rate of Settled Sewage Application (gpd/sq ft)		
(min)	USPHS[a]	USEPA[b]	GLUMRB[c]
<1	5.0[d]	b	1.2
1	5.0[d]	1.2	1.2
2	3.5[d]	1.2	1.2
3	2.9[d]	1.2	1.2
4	2.5[d]	1.2	1.2
5	2.2[d]	1.2	1.2
6	2.0	0.8	0.9
7	1.9	0.8	0.9
8	1.8	0.8	0.9
9	1.7	0.8	0.9
10	1.6	0.8	0.9
11	1.5	0.8	0.6
12	1.4	0.8	0.6
15	1.3	0.8	0.6
16	1.2	0.6	0.6
20	1.1	0.6	0.6
25	1.0	0.6	0.6
30	0.9	0.6	0.6
31	0.8	0.45	0.5
35	0.8	0.45	0.5
40	0.8	0.45	0.5
45	0.7	0.45	0.5
46	0.7	0.45	0.45
50	0.7	0.45	0.45
60	0.6	0.45	0.45
61-120	e	0.2	e
>120	e	e	e

[a]*Manual of Septic-Tank Practice*, HS Pub 526, III W (U.S. Public Health Service [USPHS], 1967).
[b]*Design Manual Onsite Wastewater Treatment and Disposal Systems* (U.S. Environmental Protection Agency [USEPA], October 1980).
[c]*Recommended Standards for Individual Sewage Disposal Systems* (Great Lakes-Upper Mississippi River Board of State Sanitary Engineers [GLUMRB], 1980).
[d]Reduce rate of 2.0 gpd/sq ft where a well or spring water supply is downgrade; increase protective distance, and place 6 to 8 in. of sandy soil on trench bottom below gravel and between gravel and sidewalls.
[e]Soil not suitable.

These costs are for tank support only and do not include expenses for building support. Figure 17 shows schematics of these methods. The above conditions assume a topography with a slope of about 30 degrees, so little excavation is required. If the topography is not ideal or if the composting latrine building must be kept low, a deep hole must be dug to install a large unit. The excavation and the deep retaining walls required greatly increase the installation cost. For the first unit at Fort Leonard Wood, MO, it cost $2500 to excavate an 8-ft-deep hole and to install a concrete footing and retaining walls on three sides of the hole. At Fort Irwin, CA, the building was supported on telephone poles set into the ground around the composting tank. The open area beneath the building was then enclosed with exterior siding. This system cost about $800 to construct (1983 dollars).

Clivus Multrum estimates that installing the composting unit would take local contractors 32 man hours; this includes assembling the unit on-site, placing and securing the support, and installing the fan and ventilation system. Clivus Multrum personnel need about 16 man-hours for complete installation. The typical minimum cost of installation quoted by Clivus Multrum is $500 (1982 dollars); this does not include the cost of a prefabricated structure to house the latrines. USA-CERL's field experience indicates that contractors take about 48 man-hours to install a unit. The prefabricated structure requires another 20 to 30 man-hours for installation. The total installation cost varies from $5000 to $7000 for site preparation, foundation work, assembly of composting latrine and superstructure, and electrical work. Installation of multiple latrines can reduce the cost per unit to between $3000 and $5000, depending on the type of foundation used and local conditions. For total costs, see the *Selection and Cost Estimates* section.

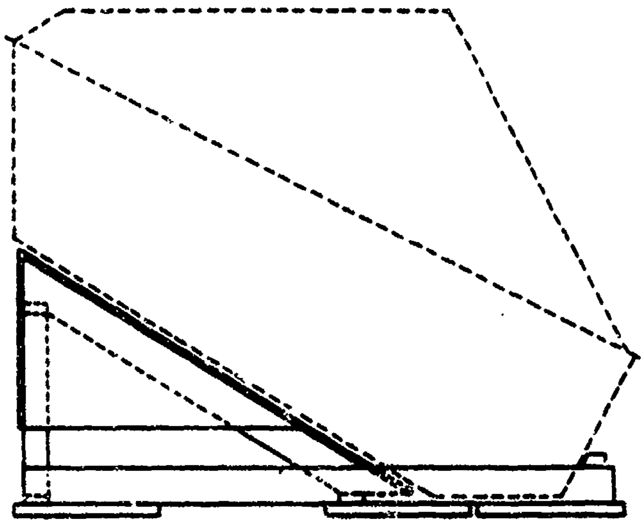
Ventilation

Ventilation supplies oxygen to the composting chamber for aerobic composting and evaporation of excessive moisture in the composting pile. Most composting units are ventilated by a natural draft assisted by an in-line fan. For example, Clivus Multrum provides a 110-V, 30-W, alternating current (AC) fan, where AC current is available. If necessary, a 12-V, direct current (DC) fan can be substituted. The fan can be powered by a solar package, which consists of solar panel, storage battery, and controls. This system is designed to operate the fan continuously, regardless of weather conditions.

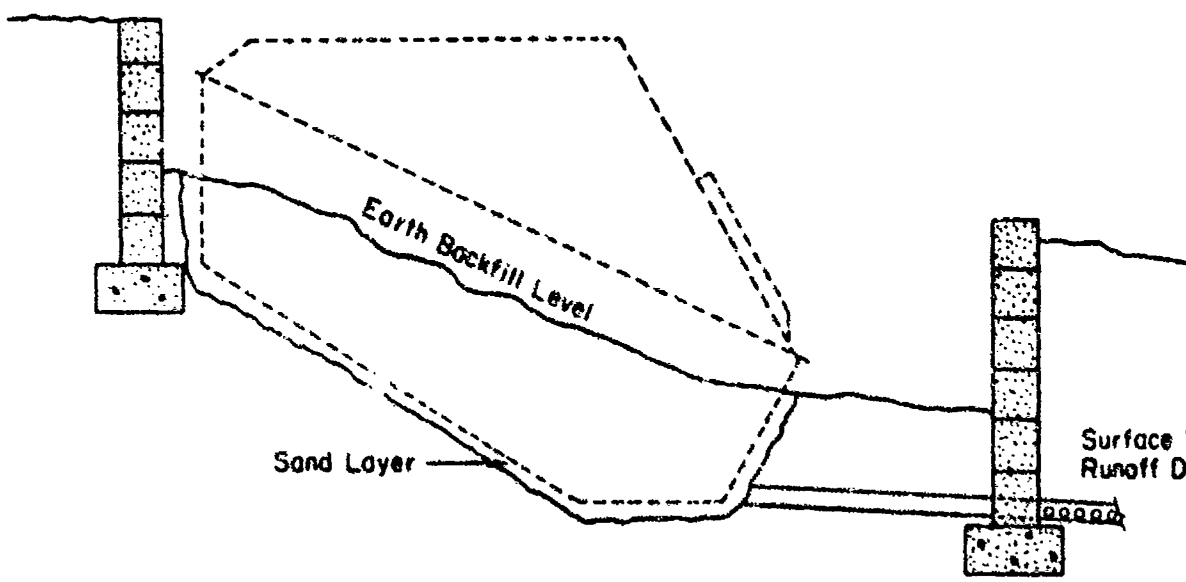
Use of a wind turbine ventilator mounted on a vent stack is not recommended. During periods of low winds, insufficient oxygen would be available to ensure proper composting and aeration.

Solar Glazing

To maintain the proper temperature for composting in cold climates, the latrine ideally should be installed inside a warm building so that heated air can be drawn into the unit for ventilation. When this is impossible (for example, at remote areas on Army installations), solar glazing can be built into the tank enclosure to aid composting on cold sunny days (Figure 18). Solar glazing can be built into any large composting latrine enclosure. However, the composting unit will serve mainly as a holding tank during cold weather with little to no degradation occurring.



Wood Support on Concrete Paving Blocks



Earth Support for Below Grade Installations

Figure 17. **Wood and earth support for composting latrines.** (From *Planning, Installation and Operation Manual for Public Facilities* [Clivus Multrum, USA, 1983]. Used with permission.)

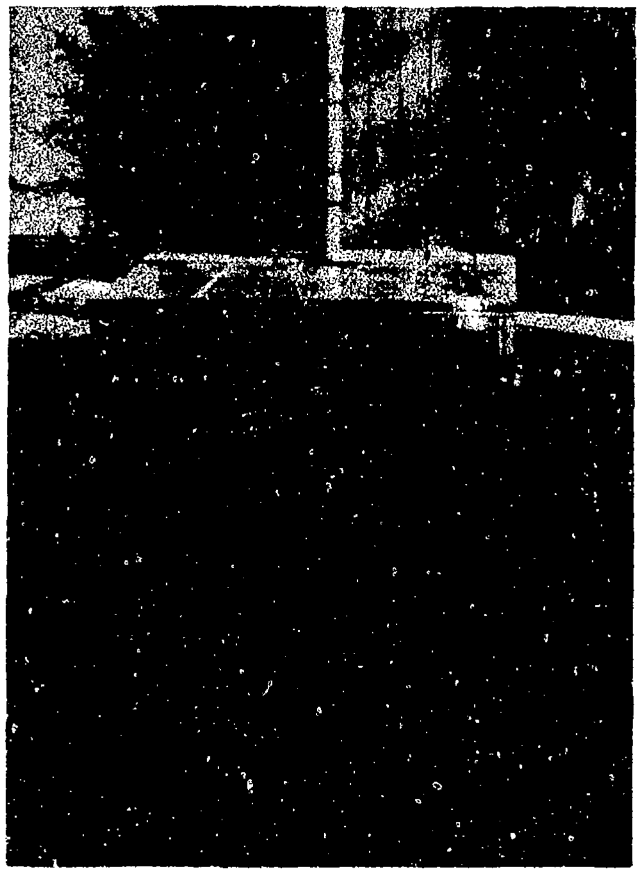


Figure 18. Solar glazing on outside of composting latrine.

Startup

To start the composting process, a layer of thoroughly moistened coarse sawdust must be packed tightly into the bottom of the composting chamber. A large composting latrine will require 20 cu ft of sawdust. One cup of liquid dishwashing detergent added to 50 gal of water can be used to moisten the sawdust.

A 2-in. layer (about 3 cu ft) of garden topsoil, forest leaf mold, or rotted horse manure is spread on top of the peat. This introduces organisms that will promote decomposition. USA-CERL has effectively used woodshavings and sawdust during startup.

During the first year of operation, there may be problems with insects, particularly flies, which are introduced with the soil and leaves. These pests can be controlled if a small amount of biodegradable Rotonone-base or Pyrethrim-base insecticide is applied to the surface of the pile. Insecticide strips can also be hung in the composting tank.

Service and Management of Composting Latrines

The literature survey and the information provided by composting latrine owners indicates that proper service and management of composting latrines in public facilities

Table 6

Problems With Composting Latrines

Complaints	Causes
Odor	Liquid accumulation. Insufficient aeration through the composting pile (latrine seats left uncovered; not enough draft; waste pile not turned or mixed). Latrine chute not properly cleaned periodically. Anaerobic conditions.
Insects	Latrine seats uncovered. No screen for window and door. Latrine use before the proper ecology is established in the waste pile. Introduced with starter or bulking agent.
Fire and explosion hazard	Cigarettes and ashes thrown on a waste pile that is too dry because of excessive draft or too much bulking agent. Solvents and explosive chemicals thrown in. Anaerobic decomposition allowed, generating methane gas (see causes of odor, above).
Unit fills up too fast (insufficient composting)	Composting process significantly slowed by cold temperatures (not enough insulation of the compost ing unit; mass of waste pile insufficient to maintain the temperature in the pile). Toxic materials added inhibit bacterial action. Foreign objects added that are not biodegradable (e.g., metal, glass, plastics). Unit receiving too much use.
Risk in handling composted material	Improper addition of bulking agent. Composted material removed too soon. Insufficient air supplied to waste pile.

are very important to reliable operation. Table 6 lists complaints about composting latrines and suggests the causes of the problems. Three basic steps can be taken to correct these difficulties:

1. Follow the manufacturer's operation and maintenance manual, incorporating USA-CERL's additional recommendations.

2. Properly train the personnel who service and manage the composting units.

3. Provide instructions to users and obtain user cooperation.

It is also extremely important to provide O & M personnel with easy access to the access chambers and doors. Sites without easy access are more prone to poor maintenance procedures.

Manufacturer's Operation and Maintenance

Every composting latrine manufacturer provides operation and maintenance manuals. Following the instructions can help ensure long-term proper functioning of the unit. Composting latrines on Army installations may have to be serviced with special care because of heavy year-round use patterns. Since the Army has limited experience with these latrines, the guidelines below are based on information about composting latrines operated by other public and private agencies in various parts of the United States, and supplemented with knowledge gained from Army experience.

Although composting latrine units for public use have a large capacity, periodic overloading can be expected. This may lead to short-circuiting of fresh waste to the "composted" section, liquid accumulation, improper mixing, and related problems. The Appalachian Mountain Club (AMC), Gorham, NH, has several years of highly successful experience with composting latrines at remote locations in the White Mountains. As a result, AMC has developed detailed guidelines for maintaining and troubleshooting large composting latrines.

The most important servicing suggested by AMC is raking the waste pile every 6 to 8 weeks. Composting latrine manufacturers do not emphasize this service enough. USA-CERL suggests that raking be done monthly. Raking the pile mixes and aerates the material, reduces excessive moisture, and provides active microorganisms with access to fresh waste material. This simple step can eliminate most problems of composting-latrine operations.

If a number of people are responsible for maintaining a composting latrine, records of use and maintenance are useful for ensuring that tasks are completed on schedule. Table 2 shows general servicing instructions for military installations. All manufacturers of large composting latrines recognize the problem of liquid accumulation. Using a leach line or pumping out the liquid is normally recommended. A 10-ft leach line is adequate for the largest composting latrine unit, as long as the surrounding soil has sufficient absorption capacity; however, the uncertain quality of the drained liquid requires further study.

Training of Service Management Personnel

Personnel must be trained to service and manage composting latrines properly. Visits to sites with operational composting latrines will give Army personnel first-hand experience with the units.

The demonstration projects recently started at Forts Leonard Wood, Dix, and Jackson provide other opportunities for training. However, it should be noted that a new composting latrine behaves differently from one that has been used for several years. During the first year, a new unit tends to have marginal composting and problems with flies, odor, and underaeration or overaeration. Operation of the 14 units now installed on Army installations has provided valuable information for future planning.

Training should start as early as possible, preferably during the design stages. The Army designer should emphasize to personnel the importance of proper service and management, and operation and maintenance requirements should be detailed in an Army Regulation. A service schedule and a method of recordkeeping should be established before startup and revised as needed.

Instructions to Users and User Cooperation

Composting latrines will fail if used carelessly, so users should be given basic rules. An instructional poster on an inside wall of the unit works well because users can be reminded conveniently and repeatedly.

The following instructions are most important:

1. Close the lid of the latrine seat after use. An open lid will restrict airflow through the pile, leading to anaerobic conditions. Self-closing lids are available or can easily be made by post personnel.

2. Do not throw lit cigarettes into the tank.

3. Do not throw trash down the chute.

Handling and Disposal of Compost

Removing, handling, transporting, and disposing of end product should be done carefully; direct contact should be avoided. Color and odor of the processed material do not indicate reliably whether the waste is composted. There may be pathogens even in a black, odorless end product. Therefore, rubber gloves and a face mask should be worn whenever handling the compost; also, personnel should wash with a disinfectant soap afterwards. Chapter 7 and Appendix I provide additional material on health considerations.

The simplest means of compost disposal is shallow burial. For example, the state of Massachusetts recommends a 6-in. minimum cover. Some states require sanitary landfill disposal; others do not specify how compost should be disposed of and allow it to be spread on open ground. Controlled burning is too costly to be an acceptable alternative, and open burning is outlawed in most states. USA-CERL recommends transferring end product in sealed plastic bags and disposing of it in a sanitary landfill.

Although these precautions might appear to be extreme, they are no more stringent than what is recommended whenever treated or untreated human wastes are handled. No matter how completely the wastes have been degraded, there is some probability of pathogenic organisms such as viruses surviving, so the wastes should be handled cautiously.

If properly maintained, composting latrines should present no health hazard to the user or to the person adding bulking agent. The only hazards are those associated with handling the wastes and compost within the composting chamber itself. By contracting out internal maintenance tasks--much like the way in which pumping of vault latrines is now handled--the health risks will practically be eliminated, since trained specialists will be the only ones handling the wastes. Results of a Health Hazard Assessment conducted by the Army Office of the Surgeon General and the U.S. Army Environmental Hygiene Agency are presented in Chapter 7. Contracted maintenance would also help to ensure regular inspections and standardized procedures. Addition of bulking agent, along with regular latrine maintenance, such as cleaning latrines and restocking toilet paper, remain the responsibility of the using troops at existing USA-CERL demonstration installations.

Selection and Cost Estimates of Composting Latrines for U.S. Army Installations

Selection Factors

This section provides guidance on sizing and selecting the proper number of composting latrines for servicing Army remote sites. The basis for this guidance is a facility in use year-round, located in a moderate climate (Missouri), and having a minimum of 50 sq ft of solar glazing on the south side of the tank enclosure. Northern (or high-altitude) locations will require more glazing or some form of auxiliary heat, such as electric unit heaters, to maintain unit capacity during the winter. Southern locations can provide equivalent service with little or no solar glazing.

The criteria for selecting the proper number of composting latrines to service a particular facility are completely different from those associated with vault or chemical latrines. Since vault and chemical latrines serve only to hold the wastes until they are removed for treatment, the only concern is that enough toilets and urinals be provided to service the troops during the time allotted for breaks. However, composting latrines are actually on-site treatment systems, so the rate at which they are loaded becomes the main design criterion. It is still important to provide sufficient seats and urinals by satisfying the loading rate requirement; this will likely provide an adequate number.

Experience to date using composting latrines on Army training ranges indicates a realistic loading rate of 50 uses per day for a large (107 cu ft) tank. This translates into one tank for every 25 troops, if the troops are on the range 24 hours a day (16 hours of training and 8 hours of sleep). If training takes less than 16 hours per day, then each tank can service proportionately more troops. An example might be a firing range which is used most weekdays for 8 hours by 150 troops. Since the range is occupied for half of the 16 training hours each day, each tank can service 50 troops. This is because fulltime use is figured as 16 hours of use and 8 hours of sleep. This rate is based on the unit having a continuously operating fan and solar glazing over the tank to aid composting during the winter. In this case, three tanks (each with two toilets and two urinals) would be required to service the 150 troops.

If a training area were used only 1 or 2 days each week, fewer tanks would be needed since the composting process can catch up with the higher loading during periods of non-use. However, in situations like this, the critical criterion becomes being able to service the troops in the time allotted for breaks. To prevent long lines at the latrine (with the subsequent time impact on training), it is necessary to provide at least one fixture (toilet or urinal) for every 15 troops. Local practice must be considered when using this figure. If troops use the latrine on an "as needed" basis, one fixture can service a greater number of troops. On the other hand, if all troops must use the latrine during a short break period (less than 30 minutes), then more fixtures are needed. A general rule is to allow an average time of 2 minutes per use. Therefore, if 100 troops must use the latrine in 20 minutes, at least 10 fixtures are needed. Due to the relatively high cost of composting latrines, it might be advisable in cases like this to extend break times slightly, so that fewer latrines will be needed. (Surveys at various TRADOC installations reveal that it is common practice to allow the troops to use latrine facilities on an "as-needed" basis with higher use during break periods.)

The Army operates many stations that are manned by four or fewer persons, such as guard stations and missile sites. For these operations, small, self-contained composting latrines (such as the Humus 80 or Carousel CR-100) are probably more appropriate. The basic differences between these and the large tank-type units are that they require

far less space for installation and use an electric heater to aid composting. The heater is needed because the decomposing mass is not large enough to retain the heat generated by the microorganisms. Their small size usually allows these self-contained units to be installed within an existing building, thereby eliminating the need for a separate latrine superstructure.

Although USA-CERL is not testing these types of units for Army use, the literature indicates that they perform well if they are not overloaded and if they are operated and maintained properly. The large composting latrine unit may also be considered for these types of stations.

Estimated Costs for Large Composting Latrine (1985)

At this time, only Clivus Multrum USA, Inc., and CTS Compost Toilet Systems produce composting toilets large enough for Army use. A third company--Human Endeavors--is now marketing composting latrines designed especially for cold climates such as Alaska. The largest tank--two toilets, one urinal, and all installation hardware, including vent stack and fan--costs about $6500 from Clivus Multrum. These units are also available through GSA, with discounts between 8 and 12 percent, depending on the number of units purchased. CTS prices are $4400 for the largest unit and 5 percent GSA discounts. This system can service about 25 people based on fulltime year-round use. If a facility is in use only part of each day or part of the year, the system can service proportionately more people. For example, one tank would service 50 people at a firing range, which is used 8 hours a day, 5 days a week.

Besides the cost of the equipment, there are costs for the building, foundation, electrical work, and installation labor. A prefabricated wood and metal 6- x 8-ft building sold with the Clivus Multrum package costs about $3800 (1982 prices) and requires about 32 hours of semi-skilled labor to erect. A site-built building of this size and durability would probably be more expensive, but might be competitive, depending on local costs. A concrete foundation for this unit costs about $3000 for excavation, form work, concrete, and backfill. A pole-constructed foundation (used telephone poles and treated lumber) costs about $1000.

In total, a completed latrine unit having two stools and one urinal costs between $15,000 and $18,000 (1983 dollars), depending on the type of foundation and local costs. Similar units for 1985 prices would cost about $20,000. A unit with two tanks and four seats would cost about $35,000. This includes installation of a 10-ft leach line, 50 sq ft of fiberglass solar glazing, electrical work for fan and lights, and all installation labor. If several units are constructed, or if multiple-tank latrines were built, the unit cost could be reduced (not counting the additional 8 to 12 percent reduction through GSA purchase). These costs, together with the improved aesthetics, reduced maintenance costs (assuming some troop support), and reduced risks of adverse effects to health and the environment, make composting a viable alternative to more conventional remote-site waste treatment systems.

Another benefit of composting is the extremely low amount of power it consumes. This feature makes it economically practical to operate the fan continuously using solar power. A solar package available from Clivus Multrum for $1200 consists of solar panels, storage battery, control unit, and DC fan. This system comes properly sized for the location and anticipated environmental conditions. In very remote areas, where the costs of providing power lines are prohibitive and the distance to a wastewater treatment plant makes waste transport costly, composting might be the best waste management alternative.

The following 1983 cost figures were determined from actual installations on Army bases. Costs could vary with local conditions and price fluctuations. Total costs per unit could be reduced by an estimated 20 percent if multiple units are installed at one time. Annual power costs will be $24 (assuming $0.10/kWh).

	Pole Foundation	Concrete Vault Foundation
Excavation and backfill (for foundation and leach line)	$300.00	$840.00
Foundation (labor and materials)	$680.00	$1,950.00
Composting unit (tank, toilets, urinals, fan, hardware, and shipping)	$6,500.00	$6,500.00
Installation labor	$1,050.00	$980.00
Prefabricated building (includes shipping)	$4,700.00	$4,700.00
Labor to assemble building	$490.00	$490.00
Electrical work (labor and materials) (assumes power within 100 ft)	$420.00	$420.00
Solar glazing (labor and materials) (50 sq ft)	$490.00	$490.00
Total	$14,630.00	$16,370.00

Estimated Costs for Small Composting Latrine (1983)

Composting unit	$2,200.00
Installation labor	$220.00
Electrical work (labor and materials) (assumes power in building)	$110.00
Total	$2,530.00

Annual power costs will be $72 (assuming $0.10/kWh). Annual operation and maintenance costs will be $240 (assuming troop labor for addition of bulking agent).

Even if there is not sufficient room in existing buildings for a self-contained composting latrine, this option might still prove to be cost-effective. Superstructure requirements are minimal since no excavation or tank support is needed. The building can be constructed on a slab, on-grade, or on skids for mobility. Although this appears to be an ideal option, it must be remembered that each unit can service only four troops on a fulltime basis.

New Developments in Composting Latrines

Clivus Multrum will soon be producing composting latrine units made from polyethylene. The new product will be 3 ft wide, 7.5 ft tall, and 1 ft longer than the current model. However, its volume will be the same. They will retail for the same prices as the current models with the 8, 10, or 12 percent GSA discount also available, depending on the quantity ordered. The shorter height requirements are anticipated to lower basement construction costs and hence lower building costs. The decreased width will also permit tighter packing of multiple units.

Maintenance contracts which are also being developed will be offered to the installation. Maintenance would be done by a subcontractor (usually the contractor responsible for pumping vault latrines and/or septic tanks) who would check all the units on a weekly basis and supply the necessary bulking agent. The subcontractor would also rake the pile thoroughly once a month and would be responsible for ensuring that the unit is functioning properly (i.e., fan operating, checking liquid level, etc.). Clivus Multrum would provide supervision and training for the subcontractor and would check periodically to ensure that proper procedures are followed. Estimates at this time are 15 minutes per week per unit and 30 minutes once a month per unit, for a total of 1 hour and 15 minutes per unit per month plus travel costs.

Human Endeavors is marketing a composting latrine designed especially for Alaska. Primary differences from the products of other manufacturers are that this tank is aluminum, which conducts heat more evenly, and is well insulated, having a 6-in. layer of polyurethane foam around it. More information may be obtained by contacting USA-CERL or the manufacturer.

6 COMPOSTING LATRINE DEMONSTRATIONS AND O&M SURVEY

Composting latrines have been used in the United States for more than 20 years and in public facilities for 12 years. Composting's potential for handling human wastes without water in an odor-free manner has made it an attractive alternative to pit and vault latrines in remote areas. Many facilities which require some form of remote waste-handling system have tried composting to determine whether it will perform satisfactorily. Although composting has worked well in private use, the number of variables involved at public facilities makes for less ideal conditions, reducing the likelihood of trouble-free operation and maintenance. Also, variations in how the units are installed from site to site make it difficult to draw conclusions concerning their overall acceptability.

Therefore, USA-CERL installed 16 composting latrines at three Army installations for testing under actual site conditions. These demonstrations showed that the performance of composting latrines can depend greatly on how they are operated and maintained. Researchers hoped that by surveying other public installations, a consensus could be reached regarding what degree of maintenance is required for proper performance under various operating conditions.

The results reported here are taken from a telephone survey of 93 public installations across the United States and Canada. Although each installation was unique, certain underlying principles became evident as the survey progressed. Although empirical in nature, the data collected allow some conclusions to be drawn.

Survey Approach

A telephone survey was chosen because the information required was to be gathered from nearly 100 installations. A questionnaire form was developed (Appendix G) based on the information needed to assess operational conditions and the performance of the unit or units. This form was used for each interview to standardize the data gathered. The same person conducted all 93 interviews to maintain consistency in explaining the questions and interpreting the answers.

The first section of the questionnaire asked for basic information about the installation. Location information indicated the type of climate to which the unit was exposed. It was also noted if the unit was located at a high elevation. In general, the person sought the unit's operator who was the one most intimately involved with the unit's daily operation and maintenance. It was quickly discovered that what a facility director thought was being done and what the maintenance staff actually accomplished did not coincide, especially at larger facilities. Whenever it became evident that the interviewee was not familiar with daily operations, another point of contact who actually used the unit or someone within the maintenance department was requested.

The type of facility was indicated to determine any similarities in operational practices. For instance, state parks might depend more on summer help, whereas county parks might have a year-round maintenance staff. Most units were outdoor restrooms or latrines. Whenever the latrines were part of another structure, such as a shower house or visitor's center, this was indicated after the type of facility entry. The number of buildings and tanks indicated the scale of the operation. All data were recorded on a per-tank basis to bring the information to a common denominator for valid comparisons.

The cost of the units, when available, was the approximate total installed cost of the restroom facility divided by the number of composting tanks installed. If the units were part of a larger facility, such as a visitor's center, the cost indicates only the purchase price of one tank and its related hardware.

The installation date indicates the unit's age. If units were installed at different times, multiple dates have been entered. All data concerning use, maintenance, and performance were taken on the oldest unit. Throughout the survey, units less than 2 years old were avoided, since USA-CERL experience has shown that a composting latrine can require this much time to become fully active. Owners of older units were generally questioned in greatest detail, since long-term experience was felt to be most valuable.

The second section of the questionnaire defined the loading on the tank. Use was characterized as being light, medium, or heavy based on an average week during the open season. The months or sessions of operation were indicated as well as whether use was primarily on weekdays or weekends. Concentrated use in one particular season or day was indicated on the survey forms. Also indicated was whether a counter was used to determine use patterns at any point to help assign a reliability to the uses indicated.

If winter use was indicated by the operator, it was noted whether the composting tank was installed in a heated or sheltered space. This information was useful in weighting the use factor, since a heated unit would have an advantage over an unheated one if both were being used year-round.

The third section of the questionnaire was used to determine how the operator operated and maintained the unit. Questions were asked regarding bulking agent addition, mixing of the pile and removal of finished compost, method of liquid removal, method of ventilation, inspection practices, and recordkeeping. Each category provided information that either directly or indirectly indicated the extent of attention being given to the unit. Indications of how much or how often a certain procedure was performed, and by whom, defined the importance the operator placed on proper care of the unit.

The fourth section of the questionnaire centered around user acceptance of the composting toilets. Questions determined whether users preferred composting latrines over other systems for remote restroom facilities. One manufacturer of composting latrines has claimed that elimination of odors typically associated with outdoor restrooms influences user treatment of the facilities; they will treat the units with greater respect, keeping them cleaner and vandalizing them less. An attempt was made to verify this claim.

One unique requirement of composting latrines is their need for a properly ventilated waste pile. If toilet seats are left open, most composting tanks will allow the airflow to short-circuit, thus depriving the bottom of the pile of its air supply. The effect this has on performance is uncertain; however, one major manufacturer of composting latrines provides signs with each unit instructing users to close seats after use to ensure proper operation of the unit. Keeping seats closed also prevents flies and other insects from entering the units and multiplying. Keeping seats closed requires either user cooperation (usually uncertain at remote restrooms) or automatic seat closers, which are a nuisance and sometimes circumvented.

In the user acceptance section, the surveyors asked the operator to determine the degree to which users were closing seats. By comparing installations with good cooperation against those where seats are often left open, it was hoped that the effect this factor has on unit performance and insect control could be established.

Also solicited were user comments--either positive or negative. Although contact between operators and users is usually infrequent, researchers felt that these comments would help establish the public's acceptance of composting latrines.

The fifth section of the survey addressed problems with the units, with specific questions on odors, liquid accumulation, rapid buildup of the pile, insects, and supply and regular addition of bulking agent. Surveyors noted whether the problem was occasional or repeated, and whether it had been resolved. Other problems that the operator could identify were also listed.

The sixth section of the survey investigated O&M costs. Since most installations do not keep accurate O&M cost records, researchers tried to obtain a cost comparison with other systems which had been used or which were currently in use. If the operator indicated that costs were higher, he/she was asked whether the higher costs were justified by improved performance.

The final section of the survey addressed operators' comments. Specific questions addressed whether they were satisfied or dissatisfied with the unit's overall performance, whether they thought it was composting the wastes or simply storing and dehydrating them, whether the initial cost was reasonable for what the system accomplishes, and whether they would buy more units if they needed additional facilities. Any general comments were also noted.

The type of facilities contacted for this survey ranged from state and national parks to highway rest stops and nature centers. Installations of composting latrines were contacted throughout most of the United States and Canada to identify any climatic or regional variations.

After the surveys had been completed, an interpretation method was devised to analyze the information. The scoring system used assigned values to O&M procedures and unit performance. This method was used because the data was empirical and could not be directly compared between installations. The same evaluator scored all surveys to minimize variations in interpretation.

The amount of use the unit received was evaluated and assigned a value of 1 for very light use and up to a value of 5 for very heavy use. Most operators neither had counters on their units nor had they done a manual count to arrive at an accurate use figure. Therefore, the use factor was assigned based on the operator's best estimate of use during the busiest season and on when the unit was available for use (e.g., such as seasons of the year, days of the week, and hours of the day).

O&M practices were divided into four categories: bulking agent, maintenance labor, ventilation, and inspection. Between 0 and 5 points were awarded based on the type of bulking agent being added and how regularly it was added. Depending on how often the pile was mixed, compost was removed, and liquid was pumped, the operator was given 0 to 6 points for maintenance labor. If the unit had a leach line, the highest points for liquid removal were given since this is the preferred method, even though it does not represent a high labor input. Between 0 and 5 points were awarded for ventilation based on the type of ventilator used (wind turbine, daylight fan, or continuous fan), and on whether the seats were usually kept closed or left open. Depending on how often and thoroughly the operator inspected the unit for proper ventilation and condition of the pile, 0 to 4 points were awarded. When these four categories were combined, the operator could receive from 0 to 20 points.

Unit performance was divided into four scoring categories: user acceptance, problems, O&M costs, and operator comments. A slightly different system was used to score performance. Since both negative and positive comments were made, a plus or minus score was possible in each category.

For user acceptance, a +1 was given if most users liked the unit, a -1 if most disliked it, and a 0 if there was no consensus or if no comments were available. In the problems category, 4 points were awarded if no problems were identified. One point was deducted for each minor problem, such as rapid liquid accumulation or occasional insects. Two points were deducted for more serious problems such as unavailability of bulking agent or occasional odors. If problems were persistent or severe, additional points were deducted, with the lowest score possible in this category set at -4.

If the operator indicated that O&M costs were lower than they were for alternative systems, a +1 was awarded. If costs were higher, a -1 was assigned. If the operator was uncertain of costs or if he/she indicated that higher costs were justified by improved performance, or if costs were comparable to those of other systems, a 0 was assigned.

In the category of operator comments, a +1 was awarded for each positive response given to the four questions asked and a -1 was assigned for each negative response. If the operator had no opinion or was not sure of how to answer, a 0 was assigned.

When the four categories for performance evaluation were combined, the total score ranged from -10 to +10. Appendix H outlines the scoring method.

Results

Most composting-latrine field operators were very cooperative, and most of them had questions regarding proper operation of the units.

Although the data collected by this survey is subjective in nature, the use of the scoring method previously described allowed for an analytical approach to interpreting the results. Appendix H lists the scores for each installation as determined from the telephone surveys. Again, it should be noted that since these scores are subjective, caution should be exercised when applying detailed mathematical analysis to them. The approach taken for this report was simply to present the data in the form of bar graphs, which indicate general trends and percentages rather than precise relationships.

Figures 19 through 31 (pages 70 through 77) depict the data for the four categories which made up the survey's O&M section. Each graph indicates the percentage of the total number of installations contacted receiving each score. Figure 19 shows that 21 percent of the installations are adding the proper amount of an ideal bulking agent, 13 percent are adding nothing, and the remainder are adding too little or an inferior material. However, it can also be seen that a solid majority (79 percent) of the installations received a score of 3 or better, which indicates that they are adding an acceptable bulking agent fairly regularly.

Figure 20 suggests that installations are not doing as well with maintenance labor as they are with regular addition of bulking agent. Maintenance labor is a combination of mixing the pile, removing compost, and maintaining a low liquid level (either by pumping or with a leach line). Only 80 percent of the installations surveyed are performing all three operations regularly. About one third (34 percent) are spending what could be considered an acceptable amount of labor (scores 4, 5, and 6). Most (66 percent) are

doing less than an acceptable amount, and almost 10 percent are doing no maintenance at all. This lack of proper maintenance results from a combination of factors. First, many public facilities are understaffed, so maintenance tends to be done only as needed to keep systems operating. If the composting latrine appears to be operating properly, nothing is done to it. Second, composting is a slow process, so the result of a particular maintenance program is not seen until the unit is emptied one or more years later. Operators assume that since the unit is not generating odors that they are maintaining it properly, when in fact it may be gradually becoming plugged due to a lack of bulking agent addition or pile mixing. Third, certain sales representatives had originally promoted composting latrines as zero-maintenance items. This has led to an "install them and forget them" attitude among some operators. Although specific maintenance procedures are now available from composting latrine manufacturers, most operators are not yet aware of them.

Figure 21 indicates that most of the units surveyed have a positive ventilation system and that toilet seats are usually kept closed. Fifty-two percent of the units have a continuously operating fan, and 35 percent have a continuous fan and have the toilet seats kept closed. Only 7 percent have no fan and have seats left open. Of all the units surveyed, more than half experience occasional odor problems. Most operators believed that proper ventilation was the key to preventing odors and that keeping seats closed reduces odors and insects. Some operators felt that a nonobtrusive automatic seat closer was needed since users of their units generally leave the seats open. A few installations had solar-powered fans. Operators with early models complained that they would not always start in the morning; however, this problem has apparently been resolved with later models. Figure 22 shows the frequency and detail of operator inspection. It appears that a solid majority (81 percent) of the units receive fairly thorough, regular inspection. Only 5 percent are never inspected. The remaining 14 percent occasionally receive some kind of check, usually for fan operation and odor level. Although these figures appear very favorable, it should be noted that an inspection alone does not improve a unit's operation. Unless a problem is solved, the inspection has accomplished little. Inspection procedures are also easily overstated since there is no physical evidence that they have been performed. There may be discrepancies between what a maintenance person claims to have looked at and what has actually been checked. Regardless, responses indicate that most operators are aware of the importance of occasional inspections.

Figures 23 through 26 illustrate performance levels in the categories of user acceptance, operational problems, operation and maintenance costs, and operator comments, respectively. Figure 23 indicates that there is a very good level of user acceptance: 66 percent of the installations received mostly favorable comments, 30 percent had either no responses or a mix of positive and negative ones, and only 4 percent had mostly negative feedback. Most operators attributed this favorable user acceptance to the lack of foul odors typically associated with remote restroom facilities.

Figure 24 depicts the number and severity of problems identified by operators. Twenty-five percent of the installations received a score of 4, which indicates no problems have ever occurred. Forty-four percent received a score of 3, indicating that slight problems occurred which were quickly resolved (for example, odors or insects were noticed only during unit startup). Only 2 percent noted serious problems such as persistent odors or plugging of liquid screens. Another 2 percent received the lowest possible score of -4, which indicates total unit failure. One of these units failed due to improper installation and an almost total lack of maintenance. The other unit was apparently an outdated design which has since been abandoned because of repeated plugging problems.

The only maintenance-related problem cited by the operators was occasional difficulty in obtaining good bulking agent and assuring that the staff was adding it regularly. This was mentioned by only a few installations, and usually only for their more remote facilities; however, this could be a serious concern for any installation, considering the influence bulking agent has on proper unit performance.

Although only a few of the installations surveyed had actual cost figures to support their claims, most (78 percent) indicated that installation of composting latrines has actually reduced their O&M costs (Figure 25). Eighteen percent gave a neutral response, indicating either that their O&M costs were about the same as with other types of remote waste handling systems, or that they had no other systems with which to compare them. Only 4 percent indicated that composting latrines had increased their operating expenses. The operators who indicated lower costs generally claimed that any added maintenance labor required by composting latrines was more than paid for by eliminating pumping costs associated with vault latrines or digging costs associated with pit latrines.

Figure 26 shows the general type of operator comments received on composting latrines. Ninety-five percent of the operators responded with favorable to highly favorable comments. Only 5 percent had more negative than positive responses. This indicates that regardless of whether composting latrines perform as well as claimed by their manufacturers, most of the public unit operators are satisfied with them. Nevertheless, many operators are uncertain about whether their units are composting or simply dehydrating the wastes. Also, most operators surveyed had not yet removed any finished product and, therefore, did not know whether their units were flowing freely or plugged.

A plugged unit does not necessarily indicate total unit failure. In fact, if detected before the unit becomes full, the pile need only be thoroughly mixed to loosen it and allowed to drop. However, if a plugged unit becomes full, raw compost must be removed from the top of the pile to allow mixing of the bottom of the pile where compaction and plugging have occurred. This can be an unpleasant and time-consuming task.

To better summarize the data illustrated in Figures 19 through 26, the scores received by each installation for O&M practices and for overall performance were combined in Figures 27 and 28. Figure 27 illustrates that when all four categories of O&M are combined for each installation, there is a large spread in the scores. This indicates that an installation that does well in one category does not necessarily do well in all categories. Apparently, modes of operation and degree of maintenance vary considerably. Where one facility might depend on good ventilation, another might find that regular addition of bulking agent controls odors. This is a factor of use, climate, availability of labor, and other variables.

Figure 27 also shows that most installations received a score of between 11 and 15. This indicates that most installations are performing less than the recommended amount of maintenance. In fact, only 1 percent of the installations received a perfect score. On the other end of the scale only 5 percent received a score of five or less.

Figure 28 illustrates the result of combining scores for the four performance categories for each installation. The tight grouping of scores and the peak at a score of 8 indicate a consensus of responses. Seventy-eight percent of the units received a score of 6 or better, whereas only 4 percent scored below 3. This indicates rather strongly that most public units surveyed are performing well.

An attempt was made to correlate unit performance to O&M practices. Due to the effects of loading on performance, the data were grouped into low, medium, and high use

ranges. Figures 29, 30, and 31 show the comparison. As expected, O&M practices had little effect on performance at low-use installations. When loaded slowly, a composting latrine can apparently adjust to any conditions and perform satisfactorily. Although the data are quite scattered for the medium- and high-use ranges, O&M practices do seem to affect unit performance to some degree. However, the relative flatness of the line in Figure 29 further illustrates the tolerance composting latrines have for inferior O&M practices.

Data Analysis

The information gathered from the 93 installations surveyed indicates that O&M practices vary greatly among public installations due to variations in management, availability of labor, and relative remoteness of the units. Also, most of the composting units receive less than the recommended amount of O&M due to lack of motivation or available labor and failure to understand the units. Finally, most units surveyed are performing satisfactorily, despite a lack of proper maintenance. So far, it cannot be concluded that these units are composting the wastes thoroughly, since the finished product has not been analyzed in detail; however, most units are reducing waste volume and eliminating the odors normally associated with remote restroom facilities.

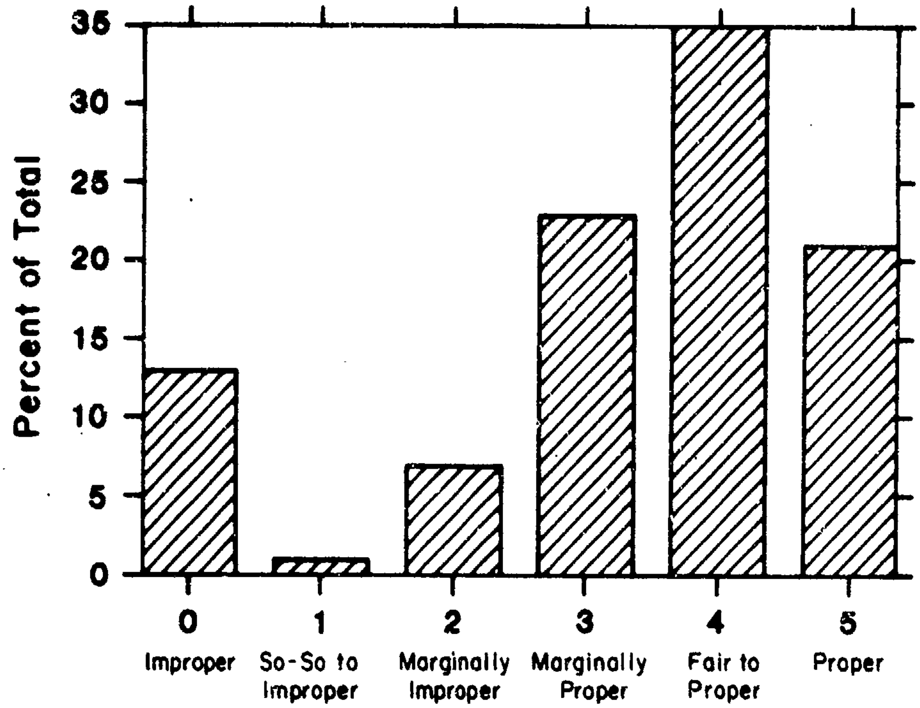


Figure 19. Bulking agent score.

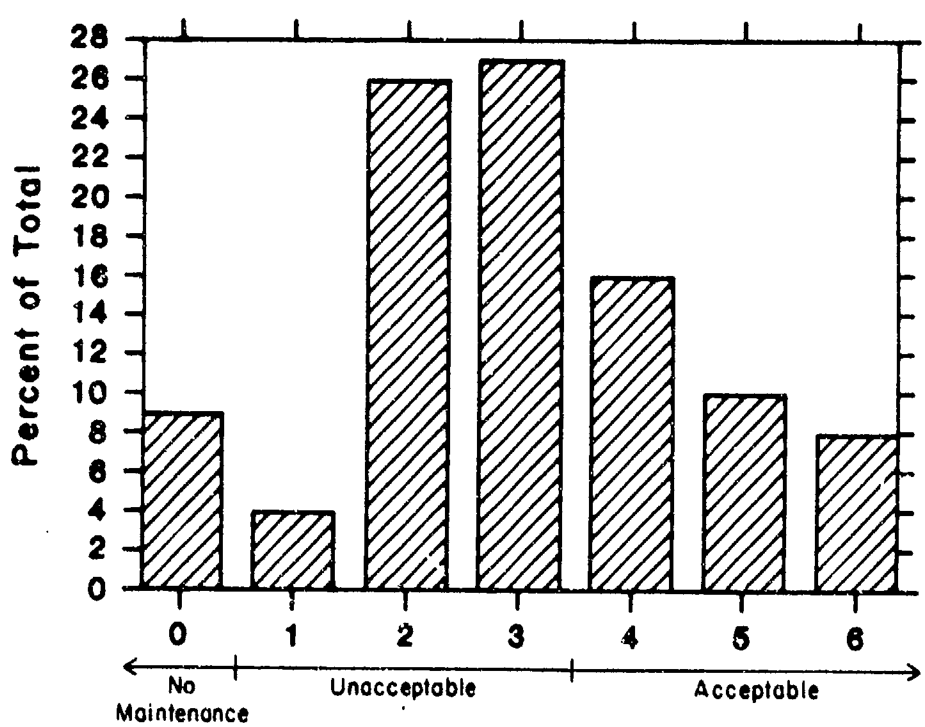


Figure 20. Maintenance labor score.

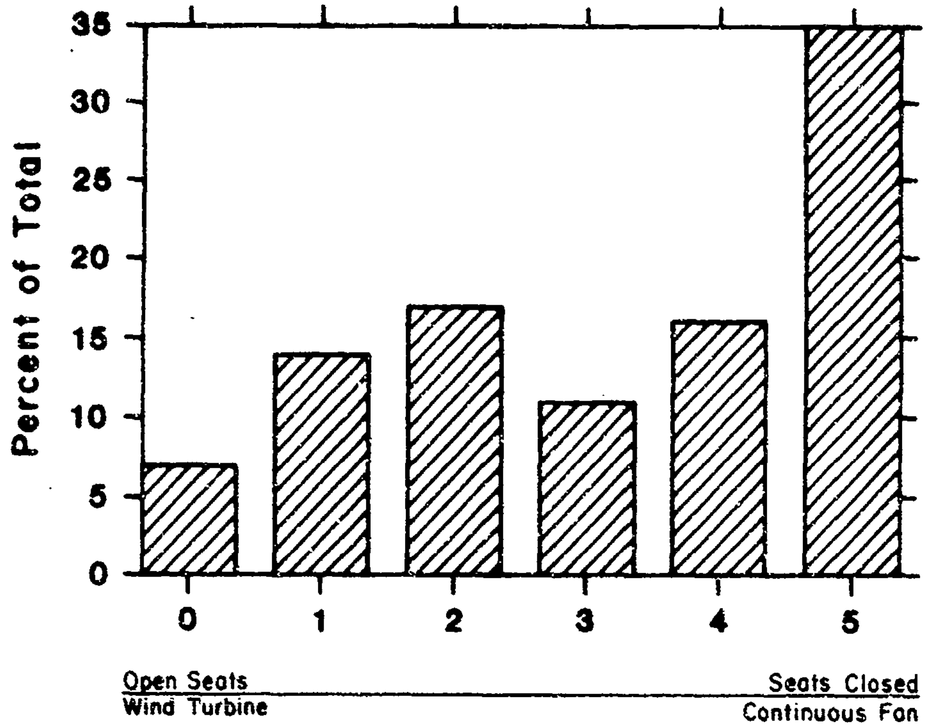


Figure 21. Ventilation score.

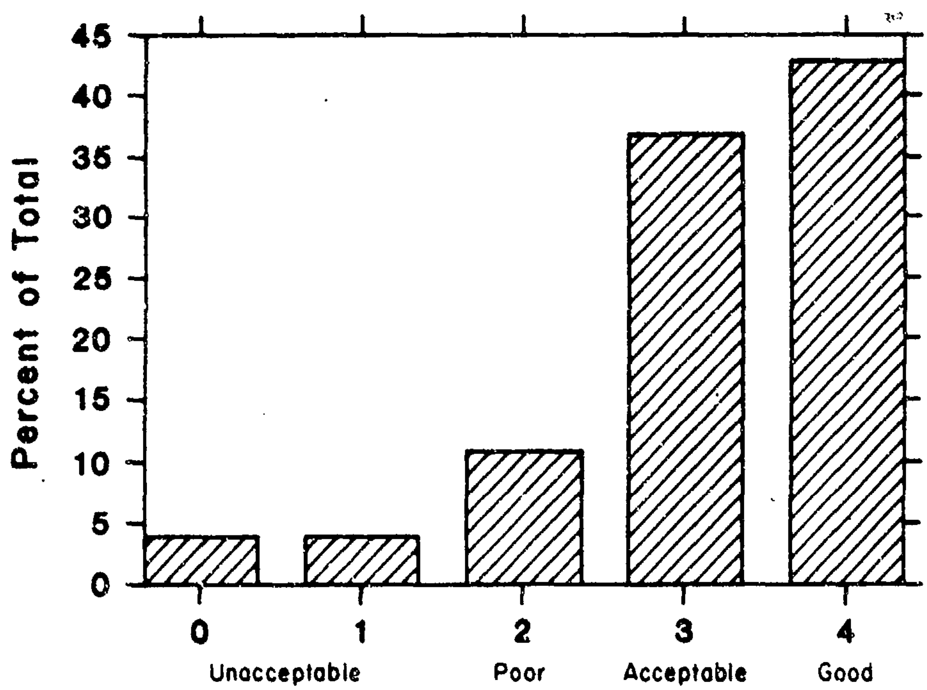


Figure 22. Inspection score.

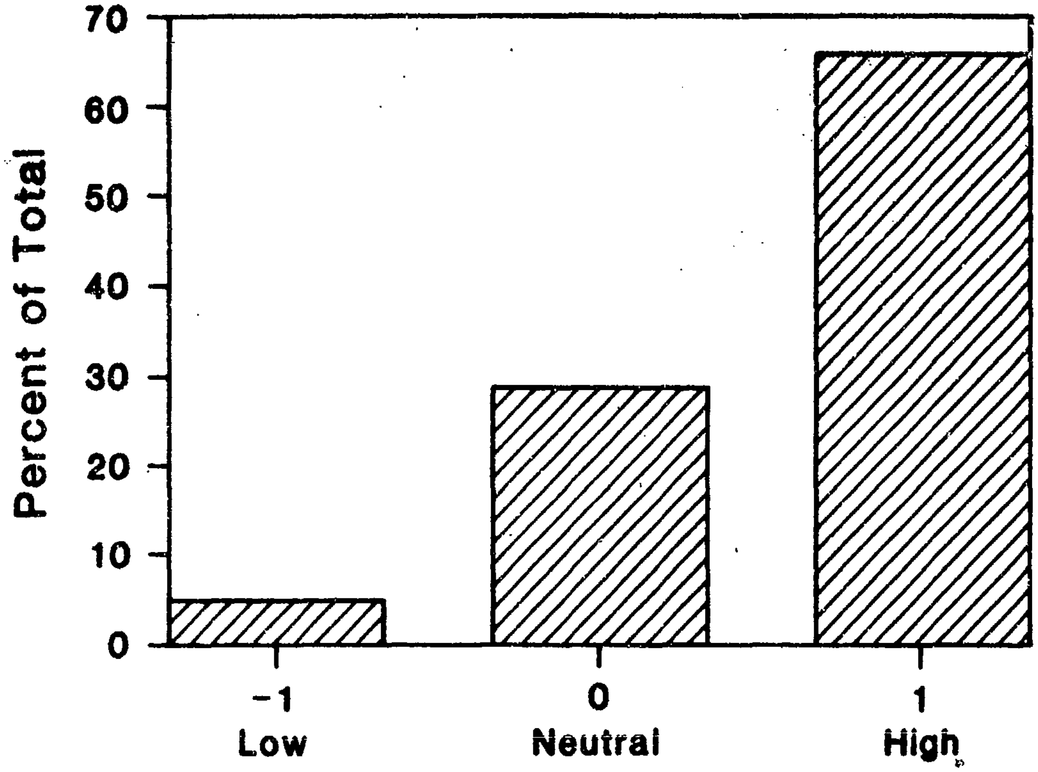


Figure 23. User acceptance.

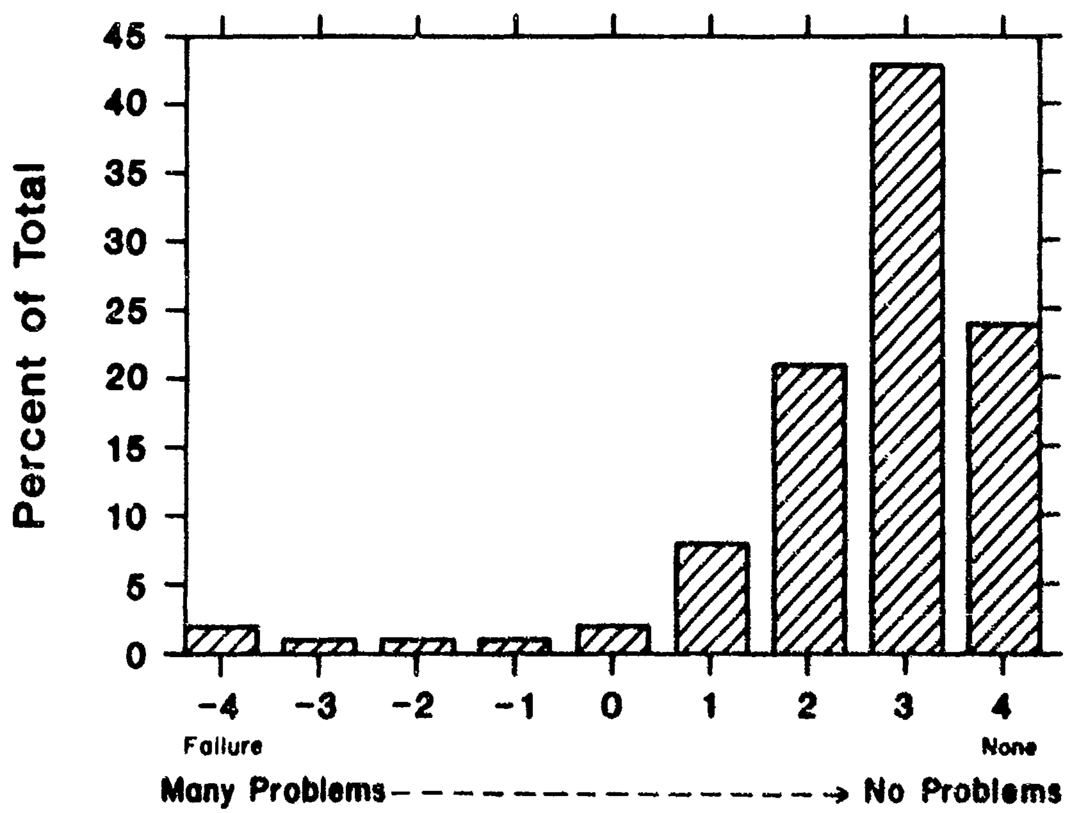


Figure 24. Problems score.

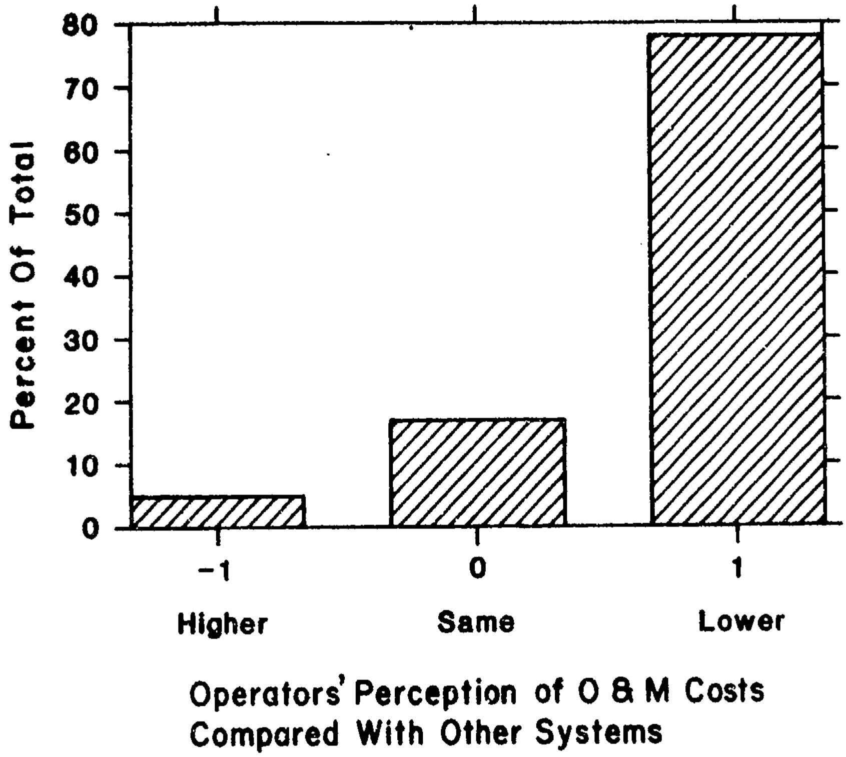


Figure 25. O & M costs.

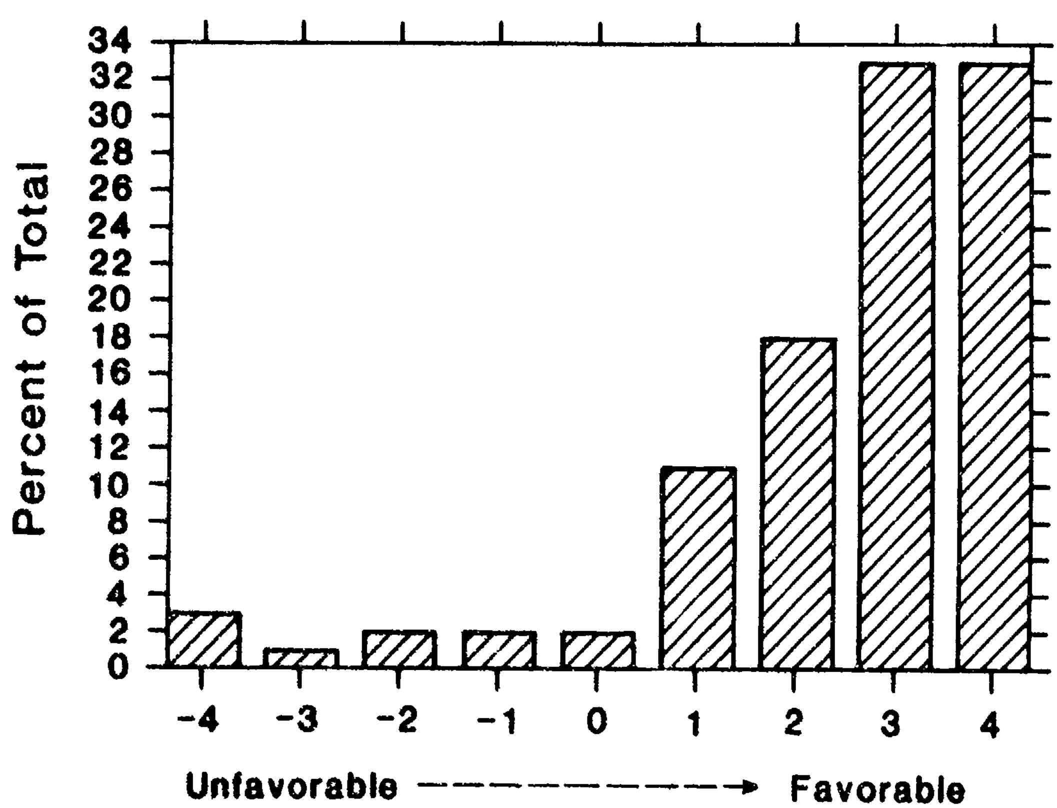


Figure 26. Operator comment score.

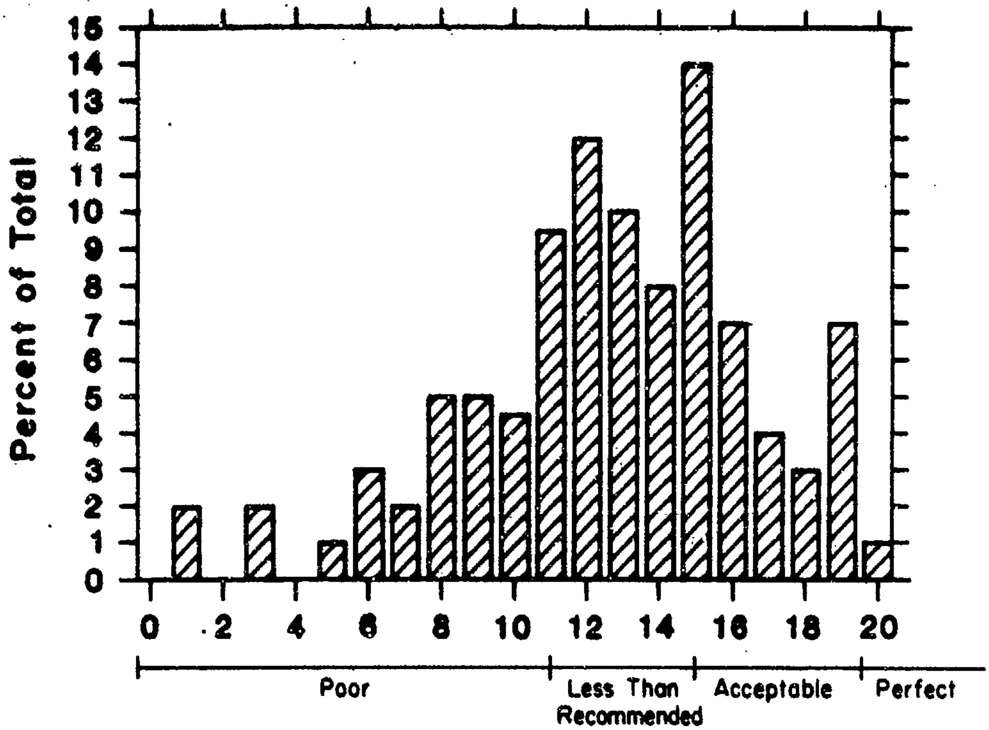


Figure 27. O&M practices.

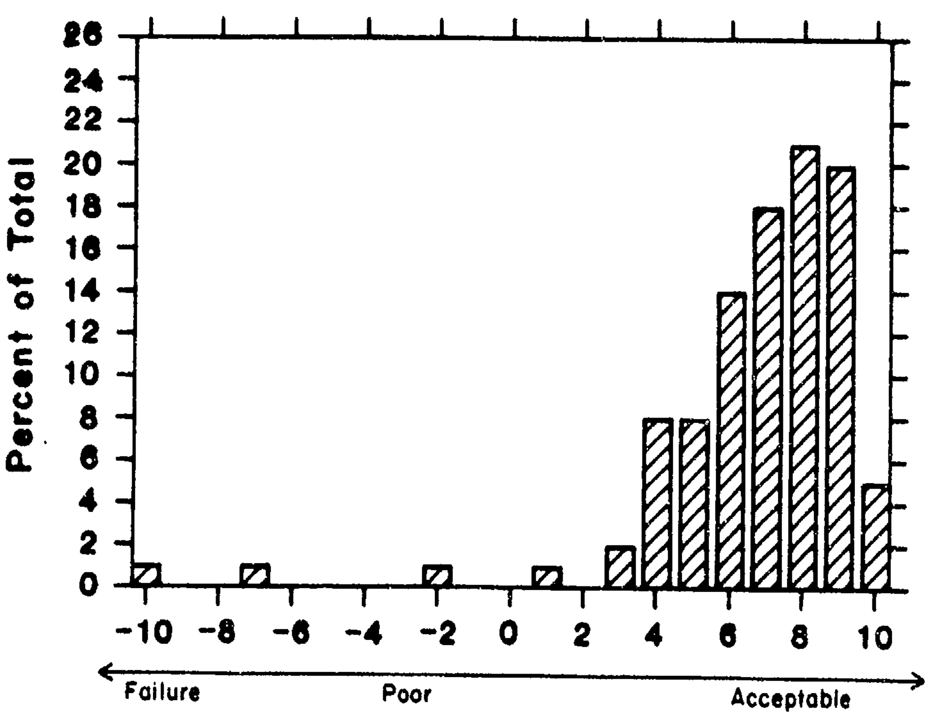


Figure 28. Overall performance.

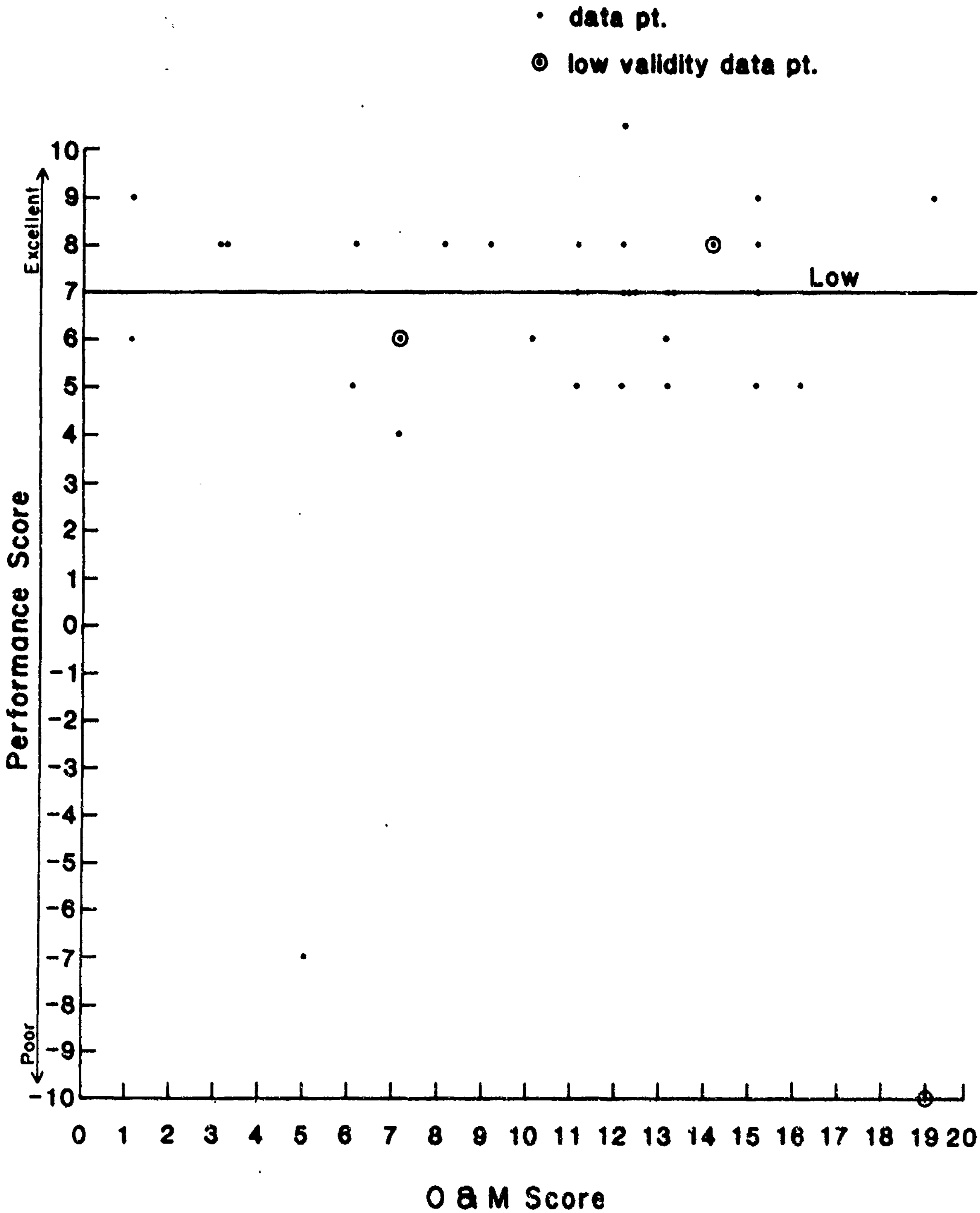


Figure 29. Performance vs. O&M scores for low-use units.

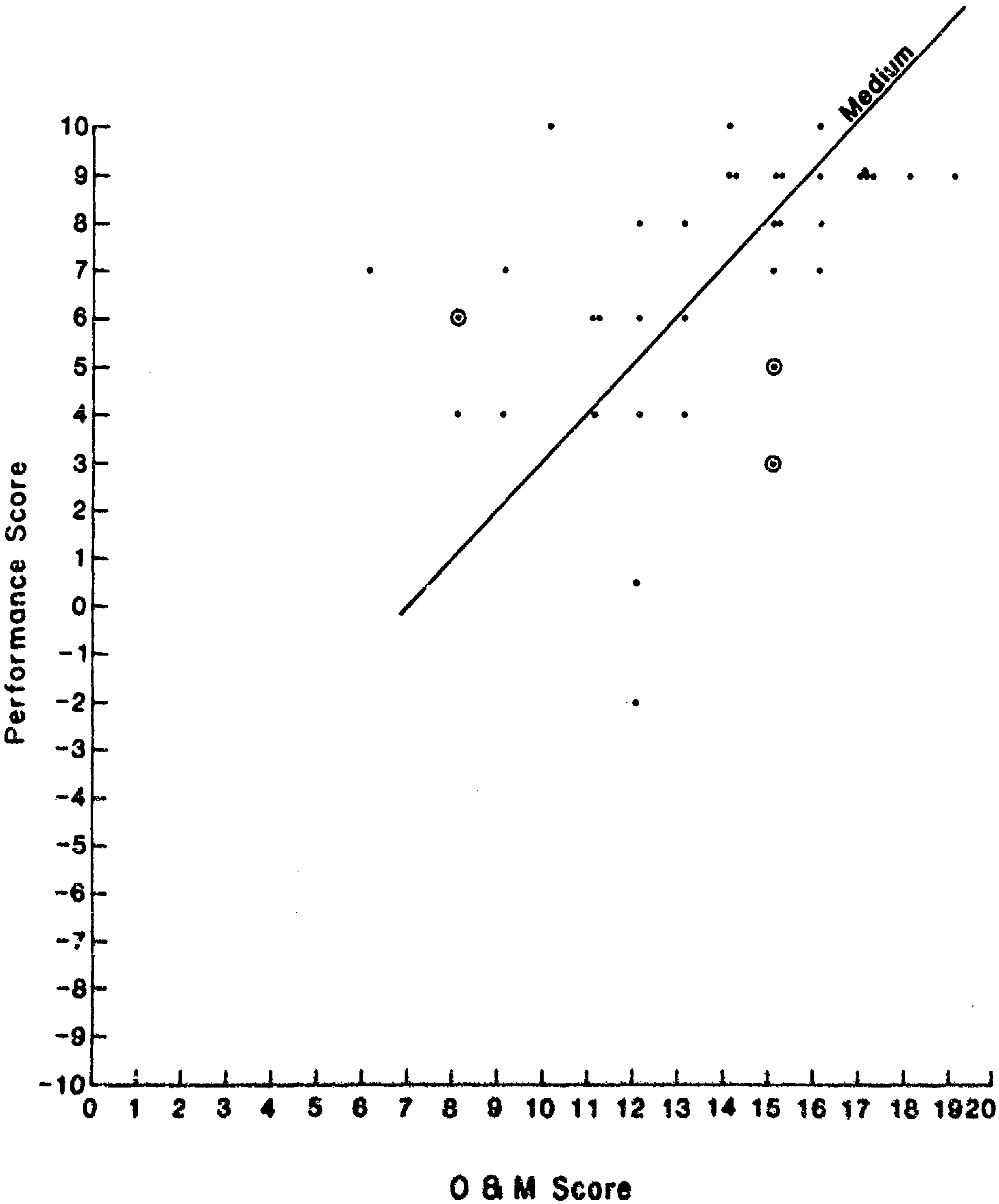


Figure 30. Performance vs. O&M scores for medium-use units.

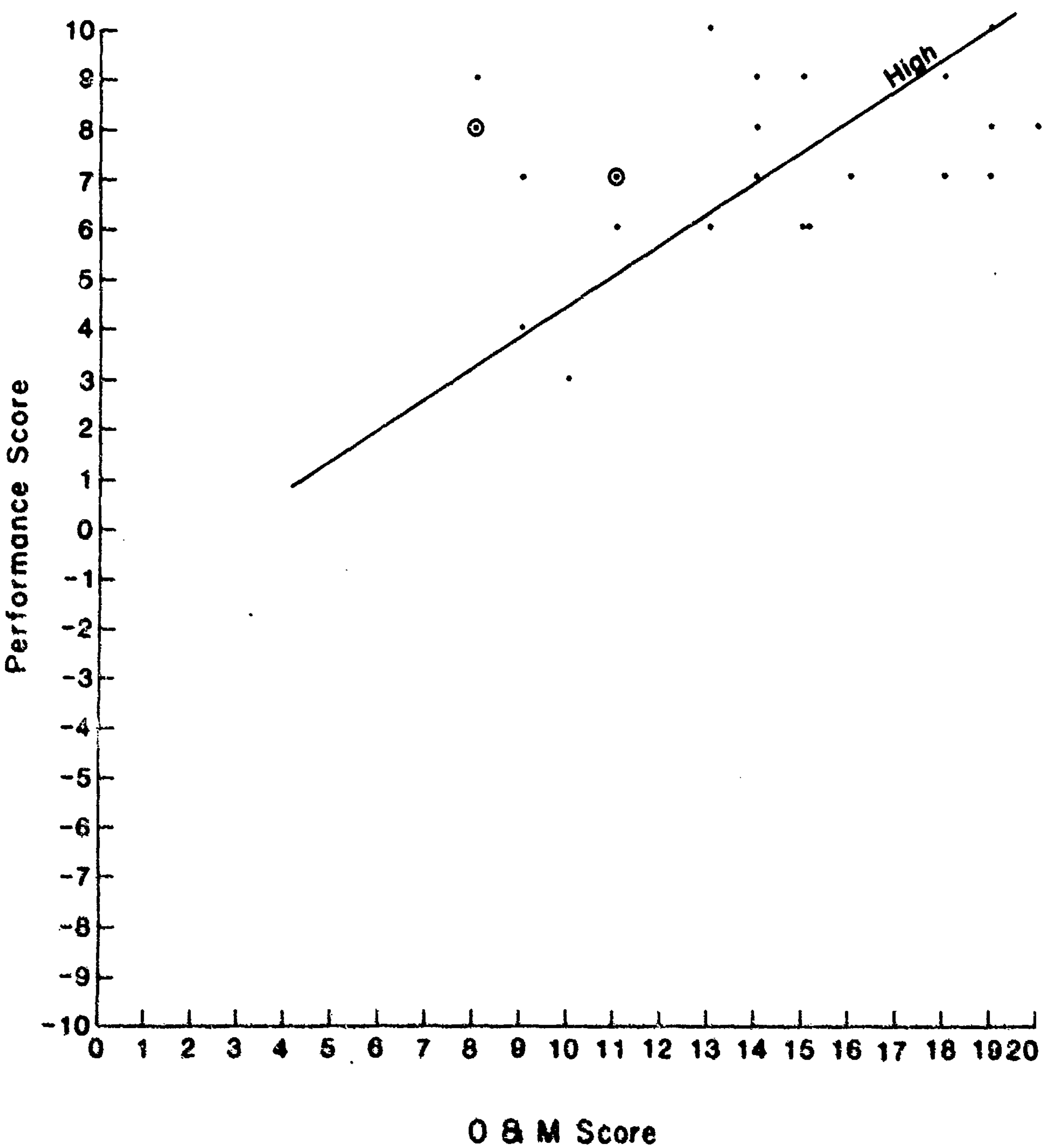


Figure 31. Performance vs. O&M scores for high-use units.

7 HEALTH CONSIDERATIONS

This chapter provides information on health-oriented information dealing with the potential risks to users and maintenance personnel of vault aeration and composting latrines. Appendix I provides a more in-depth analysis of health considerations.

Studies by manufacturers and independent laboratories on composted end-product from composting latrines have shown low coliform values, but this does not necessarily mean the pathogens have been destroyed. Studies at USA-CERL's field sites showed varied results.

Vault and chemical latrine waste basically must be considered as raw sewage and treated with appropriate care. The literature and monitoring data indicate that the risk of exposure to potential pathogens through aerosols is low for all technologies considered. To be considered a serious health hazard, there must be physical contact between the user and the waste, whether it is raw liquid waste or human waste from the raw waste chamber of the composting latrines. Composting and aerated vault processes are not considered to expose users or maintenance personnel to risks any different from those encountered in using or servicing pit, vault, or chemical latrines. However, it must be emphasized that any method of remote site waste treatment requires daily maintenance of the user area to avoid potential health problems.

The treatment processes are considered to have an occupational health risk similar to that of operating a septic tank or mechanical waste treatment system. Good personal hygiene and safety must be practiced at all times, such as no smoking and frequent hand washing with a disinfectant soap. USA-CERL recommends that waste handlers use appropriate protective equipment such as rubber gloves and boots, and use approved handling techniques. Use of protective clothing such as coveralls is also suggested. Particulate face masks are recommended where material is dry or prone to aerosols. All maintenance workers should have current tetanus and diptheria vaccinations.

The Army Environmental Hygiene Agency has prepared the following health hazard assessment for composting latrines.

1. **Identification of Health Hazard Issues.** The following potential health hazards have been identified:

a. Vector transmission of disease

b. Concentration of toxic metals and other chemicals in compost

c. Pathogen dissemination to personnel via aerosols and actual physical contact.

2. **Assessment of Health Hazard Issues.**

a. Vector transmission of disease.

(1) The greatest potential for transmitting disease is through vectors, such as the common housefly. Such problems are unlikely with composting latrines if the toilets are maintained properly. Aeration and the addition of bulking material to the chamber should considerably dilute the concentration of food available for fly breeding. Only moth flies (Psychodidae) may breed in any significant numbers; this may occur if

large amounts of liquid are allowed to accumulate due to poor maintenance. However, moth flies are only a nuisance and are of no medical significance.

(2) Locating composting latrines at remote sites could present a potential problem with rodents. However, proper maintenance will minimize this problem.

b. Concentration of toxic metals and other chemicals in compost.

(1) Accumulation and concentration of toxic metals and compounds have been recorded in conventional sewage treatment systems, usually due to inputs of industrial-type effluents. Such concentrations are not considered a problem with composting latrine facilities, when the latrines are used for their intended purpose. However, there is potential for compost handlers to be exposed to concentrations of toxic metals and other chemical compounds if the latrines are used for improper disposal of hazardous waste. Administrative and supervisory controls must be used to reduce the potential to a negligible level and to prevent regulatory noncompliance.

c. Pathogen dissemination to personnel via aerosols and actual physical contact.

(1) There is potential for compost handlers to be exposed not only to concentrated toxic metals and chemical compounds but also to human pathogens that may be in the end product. Dissemination of human pathogens by aerosols is an unresolved issue in waste disposal. With composting latrines, successful operation depends on having a forced draft with ventilation by a stack. Although the potential for aerosol dissemination seems small, further evaluation is needed.

(2) The potential for exposure to pathogens should be eliminated if compost workers use appropriate protective equipment, adhere to approved handling techniques, and enroll in the appropriate Army Medical Department (AMEDD) Medical Surveillance Program. Exposure to pathogens due to direct contact with the latrine appears to be very remote. Frequent cleaning of the latrine seat and surrounding surfaces will reduce the chance of spreading pathogens among troops and enhance the facility's aesthetics. Cleaning with ordinary soap and water is the preferred method.

3. **Recommendations.**

a. Vector transmission of disease. Ensure that appropriate administrative controls and maintenance procedures are followed to minimize harboring and breeding of insect and mammal disease vectors.

b. Concentration of toxic metals and other chemicals in compost. Do not dispose of hazardous waste and toxic chemicals in composting latrines. Use administrative and supervisory controls to ensure compliance. Perform Extraction Procedure Toxicity analysis (contact installation environmental office or EPA for details) as frequently as needed to substantiate regulatory compliance.

c. Pathogen dissemination to personnel via aerosols and actual physical contact. Clean latrine seats and surrounding surfaces daily when in use. Soap and water are preferable to germicidal agents. Use pest strips or similar materials to control insect and arachnid problems. Occasional outbreaks of insects must be controlled, and some observers have documented the presence of poisonous spiders in the units. This emphasizes the importance of good maintenance and cleaning. Other than a few mice

which sometimes nest in stored bulking agent, no mammalian vectors have been observed.

An Army Environmental Hygiene Agency Health Hazard Assessment of aerated vault latrines concluded that they are no worse than the existing situations. They offer substantial improvements for the user community.

8 CONCLUSIONS AND RECOMMENDATIONS

Traditional waste treatment technologies for remote Army sites, such as pit, vault, or chemical latrines have problems with odors, insects, vandalism, environmental contamination, and lack of proper maintenance. Composting latrines and aeration vault latrines are workable solutions to these problems, and offer substantial advantages over the traditional systems.

Investigation indicates that composting latrines:

1. Are relatively easy to install
2. Can receive required daily maintenance from troops
3. Produce little odor when properly maintained
4. Have high troop acceptability
5. Require appropriate critical regular maintenance
6. Are applicable to Army use
7. Have moderate capital costs.

Bubble aeration systems for retrofitting existing vault latrines and for new construction:

1. Are inexpensive and easily built
2. Have low maintenance requirements
3. Improve aesthetics in vault latrines
4. Reduce pumping requirements
5. Have high troop acceptability
6. Are applicable to widespread Army use.

Both systems have been demonstrated successfully on military installations and should be considered for both retrofit and new installations at remote sites, especially where there are substantial numbers of users who follow regular user patterns. Use of chemical latrines is recommended where there are very few users or where use will be of short duration. Conventional vault latrines should be retrofitted with aeration units or replaced. Where electric power is available, aerated vault latrines are recommended, provided a pumper truck can access the unit. In very remote areas, composting latrines should be considered where truck access is limited and electric power does not exist. However, vault aeration is more cost-effective and requires less labor. Either alternative is acceptable.

As a side note, TRADOC HQ has mandated the upgrade of their remote site waste treatment facilities. Aeration of vault latrines is the method of choice. If electricity is unavailable, economic analyses should be performed to determine whether it is more cost-effective to provide electricity or to use composting latrines with a solar package.

METRIC CONVERSION FACTORS

1 gal	=	3.785 L
1 cu ft	=	0.0283 m^3
1 qt	=	0.9462 L
1 in.	=	25.4 mm
1 ft	=	0.3048 m
1 sq ft	=	0.0929 m^2
1 gpd/sq ft	=	42 Lpd/m^2
°C	=	(°F -32) (5/9)
1 Hp	=	0.7457 kW
1 mile	=	1.609 Km
1 mil	=	.0254 mm

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APPENDIX A:

SHASTA LATRINES

This information is provided for supplemental interest only. The Army has no Shasta Latrine systems.

The National Park Service has prepared a report on their experiences and observations of remote area toilet facilities.[19] This appendix summarizes their experience with the Shasta waterless system.

At the time of the study, the National Park Service had about 40 Shasta Waterless Sanitation facilities in operation at various locations. Most of them had been modified in some way in an attempt to improve performance. However, four units at Grand Canyon had not been modified and allowed operations both before and after modifications to be evaluated.

Description

The Shasta Waterless Sanitation System has an open-top cylindrical fiberglass vault with a perforated fiberglass basket that fits inside the vault. The vault is buried with the top just above ground level, and a toilet riser and seat are installed in a building or privacy enclosure over the vault. The system is used like a pit toilet. Feces are retained in the perforated basket, and the urine passes through the perforations to the vault below. To operate effectively, ambient air must move downward into the tank, be warmed by biological activity in the solids basket, and then rise to be replaced by cooler air. The process depends on convective air currents to evaporate liquid in the vault and to dry the solids in the basket. All that would remain and require disposal would be dried salts from the urine and dried, possibly composted, organic matter from the feces.

Theory of Operation

The information in this section was prepared from data provided in available literature.

The intent of a dehydration toilet is not waste treatment, but rather weight reduction by liquid or moisture removal. Dehydration generally stops or severely retards biological activity. Since biological activity is the source of waste odors, a benefit of dehydration is odor reduction.

Effective dehydration requires maximizing the evaporation potential for liquid and moisture from solids. The free liquid evaporation rate can be estimated from the following formula developed for pan evaporation of water with a correction for salinity of the liquid solution.

$$E = (0.37 + 0.0041V_W)(P_S - P_W)\,0.88$$

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[19] M. E. Jensen, *Remote Area Toilet Facilities Experiences and Observations 1983 and 1984*" (National Park Service, December 1984).

where:

E = land pan evaporation rate, inches/day

V_W = wind velocity, miles/day

P_S = saturation vapor pressure of air, inches of mercury

P_W = actual vapor pressure of air, inches of mercury

The actual vapor pressure of air entering a dehydrating chamber has a fixed value, so increasing either V_W or P_S will increase evaporation. Wind velocity can be increased by increasing the air movement with fans or other methods. Saturation vapor pressure can be increased by increasing the air temperature.

The fundamental operational concepts of Shasta toilets are: (1) separating the solids and liquids, (2) evaporating the liquid, and (3) drying the solids (Figure A1). Waste solids accumulate in a slotted fiberglass basket. Figure A2 shows a 500-gallon basket. Liquids flow through the basket slots and accumulate in the container below the basket. Natural convective air movement causes outside air to enter the structure side vents and move through the basket slots into the liquid chambers. Biological action transforms and heats the solids. The warm solids heat the air, which rises and is drawn out the vent by wind movement past the end of the vent. Additional air is drawn into the basket when the toilet seat is open. The airflow allows liquid to be evaporated from the solids accumulation to dry the material. When the basket is full of solids, the building superstructure is set aside, the solids basket is removed, and the hinged basket bottom is released to dump the solids. Any structure may be placed over the unit. The basket and outside container come in a variety of sizes and shapes and are made of fiberglass for reliability and long life.

The poor performance of Park Service units suggested there were flaws either in the design or application of the operational theory, or in the installation procedure. As long as the urine level remained below the solids basket, there was little odor. However, once the liquid level reached the solids, the odor around the facility became almost unbearable. At Grand Canyon, there did not seem to be a strong enough driving force to cause natural convective air currents. Without the necessary air movement, there was hardly any evaporation, and the entire tank and basket filled with liquid and solids.

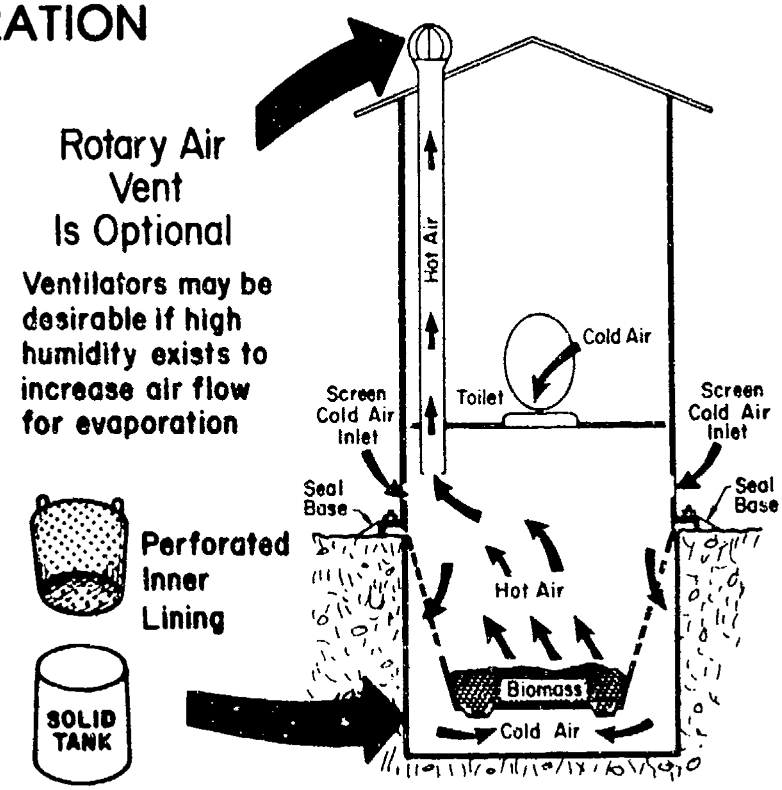
Several Shasta units installed in accordance with the manufacturer's recommendations were not performing as advertised. The units filled with liquid and caused odor and fly problems. A review of the system concept indicates several possible flaws. Use of just *any* available or *desired* structure does not provide proper venting. Most latrine structures do not have the lower side vent openings (see Figure A2) that allow ambient air to move into the basket and liquid chamber. The air must enter the basket through the toilet seat. Also, the user compartment of most latrine structures is not vented adequately or properly. The sun heats the structure and warms the air inside. The warm air rises and convectively moves from the basket into the user's compartment, rather than flowing downward into the basket. Thus, the major airflow will be up through the open toilet seat, not out of the vent.

The slots in the basket are quite narrow, and develop significant resistance to airflow. Once the air is in the basket there is no driving force to cause it to move downward through the narrow slots into the liquid chamber; as the basket fills, the slot area is reduced steadily until the slots are covered completely. If biological action in the solids produces any significant amount of heat, the air in the basket becomes heated and rises

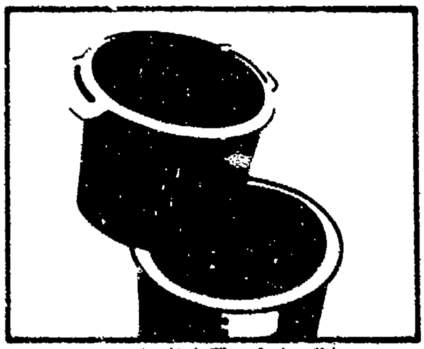
DYNAMICS OF OPERATION

Assuming the user will use reasonable housecleaning maintenance on the above ground structure, this system will remain odorless and sanitary. This system has been scientifically developed using the principles of evaporation and dehydration.

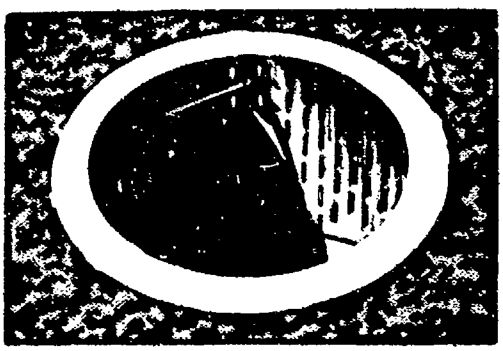
The perforated inner tank is recessed several inches from the outer shell to allow liquids and solids to separate. The liquids evaporate and the solids dehydrate, which is the basis for its odorless operation.



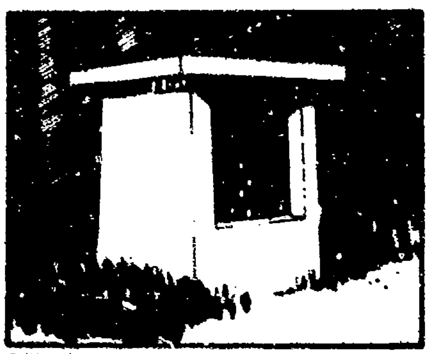
STEP 1: Backhoe Digs Hole



STEP 2: Solid Tank In Place, Inner Liner Inserted



STEP 3: Completed System Installed



STEP 4: Above Ground Structure Bolted to System

Figure A1. Shasta unit operations.

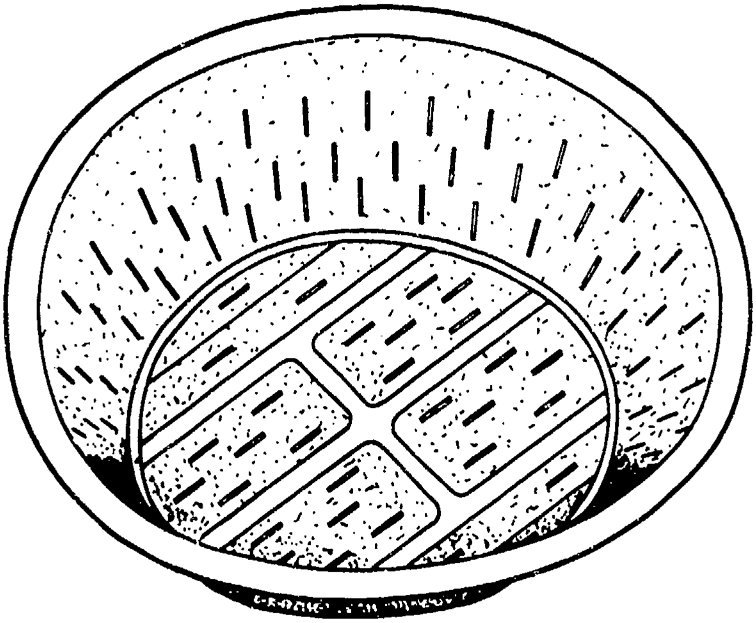


Figure A2. Shasta 500-gallon basket.

immediately. At some installations, it was noted that there was little or no clearance between the basket sidewall and the container sidewall; therefore, any air exchange had to occur primarily through the bottom of the basket. As solids fill the basket, the lower liquid chamber begins to resemble a loosely corked bottle. Since there is no significant moisture removal, the liquid accumulates until the solids are submerged.

While the solids and liquids remain separated, there are few odor problems. The solids pile, while having an anoxic core, has a loose exterior aerobic layer. Noxious gases produced in the center are used and removed biologically by the aerobic outer layers. The process is similar to the balanced system in a facultative lagoon. However, once the solids submerge, anaerobic decomposition of the solids occurs throughout the entire mass. The resulting odors attract flies and cause unacceptable odors.

Even if the liquids do not submerge the solids, the solids remain wet and are rewet with each use. New solids are deposited on the existing wet pile and retard or stop any interior drying. No natural action will rapidly dry the interior of a large pile and produce the desired weight reduction.

If the baskets were allowed to fill with saturated solids, a rough calculation indicates that a 250-gal basket (250 gal x 8 lb/gal) would weigh 1 ton. Heavy equipment, which is not available in remote areas, would be needed for removal and handling. The alternative would be frequent dumping of a partially filled basket. The inner portion of the pile would be anoxic, and when the basket is dumped, there would be significant odor problems. It also appears that handles for lifting the basket are inadequate for the potential weight and are further weakened by corrosion. It would be hard to remove the full basket without severely damaging it. The design loadings appear to be empirical and of questionable value in size selection.

The manufacturer has been very cooperative in providing buyer-directed changes, but has not modified the unit's basic design. Several units were field- or factory-modified to provide a conduit extending from the liquid chamber through the basket to some point outside the structure; this allowed the liquid to be pumped without having to remove the structure and the basket. The liquid removal prevents the solids from being submerged and avoids the odor problem. The operation and performance of the pumped unit is similar to that of a vault latrine, and vault latrines are not considered appropriate for remote National Park Service backcountry areas because of the difficulties, expense, and unpleasant tasks associated with removing the material for disposal.

Failure of a process because of overloading is not uncommon. Reliable data on usage were not available, but some of the malfunctioning Shasta units were at sites that had the potential for significant overuse; however, other malfunctioning units were at sites where use was controlled at levels well below the manufacturer's sizing information.

Since evaporation was ineffective, it was necessary to pump the liquid, which was a mixture of urine and liquified feces. The remaining soggy feces then had to be shoveled into appropriate containers for transportation to an acceptable disposal site.

The poor results obtained from these facilities were very disappointing. However, if this system could be made to perform effectively, it would greatly reduce human waste disposal problems in remote areas. Urine is about 94 percent liquid, and feces are about 70 percent liquid. Using the Shasta process for liquid removal would substantially reduce the weight of the material that would have to be transported to a disposal site. Off-site disposal would keep organic material out of the ground and ground water.

The Shasta units had mechanical problems that contributed to lack of air movement; structural problems also allowed the outer vault to deform, which wedged the basket permanently in place. Thus, at normal loading rates, the units did not evaporate the urine or dry the feces adequately. Many of the baskets could not be removed, and the contents had to be shoveled out.

Modified Shasta Waterless System

Several modifications were made to obtain better performance from the Shasta units. Modified units were studied at Glen Canyon National Recreation Area (three units), Grand Canyon National Park (five units), and Fossil Butte National Monument (one unit).

The modifications had the following objectives:

1. Improve ventilation to evaporate urine, dry the feces, and improve the environment in the user compartment.

2. Heat the air entering the evaporation compartment to increase the evaporative potential.

3. Keep the feces from being inundated by urine.

4. Keep urine from continually wetting feces in the basket.

5. Divide the solids basket into two or more chambers so solids in one chamber dry while another chamber is in use.

Ductwork and fans were used to force-ventilate the liquid and solids compartments. The forced ventilation was installed to remove air from the compartment below the latrine riser. When the seat lid was lifted, air was drawn down the riser so any odors from the tank did not rise into the user area. In most cases, the fans were operated by direct-current motors powered by photovoltaic panels. Some fans were directly connected to the photovoltaic panels and operated only when the sun was shining; others operated continuously from batteries charged by the photovoltaic panels.

The second objective was accomplished by using solar heat collectors to heat the air being drawn into the evaporation/drying chamber. The solar panels were located above the drying chamber so additional fans were needed to force the hot air down. Where terrain permits, the solar panels could be placed below the evaporation chamber and the heated air transferred by convection.

To keep the feces from being inundated in urine, a drain pipe was installed in the vault below the level of the solids basket. The drain pipe terminated in a drainfield, drainpit, or holding tank that required periodic pumping and liquid disposal.

To reduce the continuous wetting of solids in the basket, a urinal was piped to drain into the liquid vault below the solids basket.

The last objective was accomplished by constructing a perforated wall down the center of the inner basket of a 500-gal Shasta unit, and providing alternate locations for installing the latrine riser and seat.

Fans installed for forced ventilation had a noticeable positive effect on the solids drying and an assumed benefit to evaporation; however, the unit was not used frequently enough to quantify urine evaporation.

It was difficult to determine if heating the air that entered the chambers was effective. The small slots in the basket and the close tolerance between the sides of the inner basket and the liquid vault made it very difficult to develop effective air movement for solids drying or liquid evaporation.

Use of the drain pipe was successful, since there was no solids inundation in units where this modification was made. The pipe invert should be positioned at least 4 in. below the bottom of the solids basket and at an elevation that will not allow urine to submerge the exhaust vent. Liquid disposal systems can be conservatively designed based on an input of 6 gal of urine per 100 uses. A 4-in.-diameter pipe installed from outside the unit through the solids basket to the liquid storage area allowed the liquid level to be monitored, and liquid removed if necessary. The pipe is a conduit, not a suction line.

The new urinal piping did not noticeably reduce solids moisture.

All of the modifications demonstrated visual improvement in the appearance of the waste mass; however, there was not sufficient time or use of the units to determine their individual effects on urine evaporation rates.

Probing of the solids indicated they were not dry; however, they were not soggy either. A low amount of use allowed the solids to dry; the solids also appeared drier in areas subjected to continuous fan operation. During the short period of the study, there

was no evidence of biological stabilization of the material. For disposal, the solids must be handled as raw sewage, and anaerobic conditions in the inner material should be expected to produce significant odor problems during handling.

The solids will have to be removed periodically, either by hauling the basket to a disposal site, or by hand shoveling the solids into appropriate containers for transportation by helicopter or pack animal. The solids from modified latrines were not as offensive as the soggy material in tanks that had filled with liquid. The structure of the solids basket and lifting brackets was not adequate to handle a full load. Thus, if the basket is to be removed for solids disposal, it should not be more than one-third full.

Analysis

Data collected at Grand Canyon indicate that solids produced at various locations vary significantly. Toilet paper is not provided at remote latrines in the canyon. At facilities used mostly by visitors on short day hikes, the solids production is about 0.4 gal per 100 users. At facilities used mostly by campers, who would generally have toilet paper with them, solids production is about 2.0 gal per 100 users.

Solids must be removed periodically from the slotted basket and hauled to an appropriate disposal site. Salts will concentrate in the Shasta tank when urine evaporates. The basket must be removed periodically to pump the salts out as a slurry or to shovel them out if they are dry. Urine that cannot be evaporated or discharged to a drainfield at the site must be pumped from the tank and transported to an appropriate location for disposal.

APPENDIX B:

SURVEY OF REMOTE SITE WASTE TREATMENT PRACTICES AT U.S. ARMY TRADOC AND FORSCOM INSTALLATIONS*

Fort Belvoir, VA

Point of Contact

Mr. McLauglin, Chief, Environmental and Natural Resources Division, (703) 664-4131

Composting and/or Aerated Vault Latrines

Fort Belvoir has no composting or aerated vault latrines; however, they want to construct two composting latrines: one at a recreation area in a wildlife refuge and another at a firing range. The firing range latrine is reportedly in the 1988 Military Construction, Army (MCA) program.

Other Latrines

Fort Belvoir uses 84 government-owned chemical latrines and contracts for the pumping and cleaning. The monthly cost is $2000 or about $24 a unit each month. Maintenance is performed when requested. Each year, Fort Belvoir must replace about 25 chemical latrines, which currently cost $325 each. From this experience, the average life of a chemical latrine is 3.4 years.

Fort Benning, GA

Points of Contact

Mr. Divinyi, Chief, Environmental Office, (404) 545-4957

Mr. Duncan, Chief, Sanitation Branch, (404) 545-3762 or 4310

Mr. Gordy, Engineering Division, (404) 545-1932

Mr. Reese, Construction Inspection Branch, (404) 545-4749

Composting Latrines and Aerated Vault Latrines

Fort Benning has installed six composting latrines and is planning to put in six more. Mr. Gordy, an engineer with the Engineering Division, designed the units and is very enthusiastic about their use at Fort Benning. Mr. Duncan, Chief of the Sanitation Branch, does not share Mr. Gordy's enthusiasm. He has not put the composting latrines into operation because of concerns over high maintenance requirements and fears of explosions. They do not have any aerated vault latrines.

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*This survey was performed by Robert Grodt and David Hubly, of the University of Colorado, Denver.

Other Latrines

Fort Benning has 70 vault latrines. The pumping is done by a contractor who is paid $14,000 a year to pump out forty 300-gal garbage (food) containers once a week, 40 to 50 grease traps once a month, and the vault latrines as needed. The cost for the latrines is not specifically identified in the contract.

Fort Bliss, TX

Points of Contact

Mr. Rab, Chief, Environmental Office, (915) 568-5502

Mr. Carlson, Utilities, (915) 568-5233

Mr. Wolfe, Contracting Office, (915) 568-4718

Composting and Aerated Vault Latrines

The installation does not use composting or aerated vault latrines.

Other Latrines

Fort Bliss is using chemical latrines both for permanent installations (a year or more) and for temporary purposes. They have about 490 permanently installed chemical latrines and an average of 20 to 30 temporary latrines, all of which are leased. The costs vary according to distance from the installation and length of rental. The monthly rent is $35 for latrines placed at the north end of McGregor Range, 80 miles from Fort Bliss; for latrines closer to Fort Bliss, rental is $26.50 a month. For short-term rental, the cost is $12.50 a week. The contractor pumps and cleans the permanent latrines twice a week and the temporary latrines once a week. The contractor will pump more often if requested, charging between $4.50 and $6 for each pumping. These added pumping charges vary with the distance of the latrines from Fort Bliss. Mr. Wolfe estimates they pay an average of $14,000 a month for chemical latrines.

Fort Bragg, NC

Points of Contact

Mr. Anderson, Chief, Maintenance Division, (919) 396-7905

Mr. Stauer, Contract Specialist, (919) 396-2618

Composting and Aerated Vault Latrines

Fort Bragg does not have any composting or aerated vault latrines. They have considered using composting latrines but found them too expensive. They have no plans to reconsider this decision.

Other Latrines

Fort Bragg uses portable chemical latrines and vault latrines. The vault latrines are built to a Forest Service design. They also lease an average of 560 chemical latrines for use during military exercises, including ROTC training during the summer. There are 160 chemical latrines in permanent positions; the remaining 400 are moved around as needed. Military units call the Facilities Engineer Resource Management Office to obtain the latrines. The contractor charges $39.50 a week for the latrines, which includes cleaning and pumping them twice a week. Fort Bragg also has five vault latrines, which they plan to close down. A pumping contractor charges $7 to pump the 500-gal vaults under a contract that includes pumping of the septic tanks.

Fort Campbell, KY

Points of Contact

Mr. May, Chief, Operations and Maintenance, (502) 798-8987

Mr. Cassidy, Contracting Specialist, (502) 798-5514

Composting and Aerated Vault Latrines

Fort Campbell is not using composting or aerated vault latrines. The installation tried to buy and install a composting latrine several years ago, but had problems with funding limitations related to the latrines being considered TDA (Table of Distribution and Allowances) and Base Civil Engineer (BCE) equipment.

Other Latrines

Fort Campbell uses chemical and vault latrines for remote sites. They use about 50 government-owned chemical latrines and lease about 20 more each year for special events such as ceremonies and unit parades. The chemical latrines originally cost $300 to $400.

The troop units must pick up the chemical latrines, which are stored at the sewage treatment plant, and take them to locations where they are needed. The units must also provide a "guide" to meet and escort the contractor to the latrines for cleaning and pumping. The troops are responsible for providing toilet paper and daily cleaning. Some of the government-owned latrines are permanently placed at ranges and at the installation gates. The latter are principally for use of the gate guards. There are 20 to 24 vault latrines located throughout the post, but fewer than half are used. Some have never been used. The vaults were originally put in without a structure on top. Some have buildings added, while others do not. They are pumped as needed. When Fort Campbell had a local servicing contract, there were no problems with maintenance. However, the present contractor is not local and is not as responsive as the previous firm. There have been problems with their system of using troops to move the latrines. Requests are to be in 2 weeks early, but often come in at the last minute. Troop guides show up late or not at all, thereby delaying the contractor. Another problem is that the chemical latrines freeze during the winter.

Carlisle Barracks, PA

Point of Contact

Mr. Messerschmidt, Chief, Engineering Plans and Services, (717) 245-3501

Composting and Aerated Vault Latrines

Carlisle Barracks, a small post principally supporting the Army War College, has no ranges and conducts no field training. Thus, they have essentially no sites where composting or aerated vault latrines would be applicable.

Other Latrines

The installation uses a small number of chemical latrines at special events such as open houses, parades, and ceremonies. They prefer the chemical latrines to fixed facilities, because they can increase or decrease the number used and move them as needed.

Fort Carson, CO

Points of Contact

Ms. Barber, Environmental Specialist (303) 579-2022

Ms. Leach, Contract Specialist

Composting and Aerated Vault Latrines

Fort Carson does not use composting or aerated vault latrines either on the installation or on the recently acquired training area at Pinon Canyon. However, they would like to install some composting latrines at Pinon Canyon on a test basis.

Other Types of Latrines

Chemical latrines are widely used throughout the installation. The Training Division of the Operations and Training Section (G-3) manages the latrines. Ms. Leach with the G-3 Budget Office stated that the chemical latrines are leased for $30 a day or $5800 a year. They recognize that the prices are high and are considering a recommendation to buy rather than lease them.

Fort Chaffee, AR

Point of Contact

Mr. Yada, Chief, Engineering Plans, (501) 484-2777

Composting and Aerated Vault Latrines

Fort Chaffee is not using composting or aerated vault latrines.

Other Latrines

Fort Chaffee is using vault latrines and chemical latrines. So far, information about the numbers and the costs of the latrines has not been provided.

Fort Devens, MA

Points of Contact

Mr. Nichols, Chief, Energy and Environmental Management, (619) 796-3002

Mr. McIntosh, Range Control Officer, (617) 796-2723

Composting and Aerated Vault Latrines

Fort Devens has considered using composting or aerated vault latrines, but found them too expensive. Also, Mr. Nichols had heard a rumor that one (composting latrine) had exploded. He felt that composting latrines can be used, particularly in environmentally sensitive areas, but felt they would not work well at Army installations. His concern was with maintenance problems, particularly if troops would be doing the servicing. He felt that Facilities Engineering personnel could maintain them better than could forestry or buildings and grounds personnel.

Other Latrines

Fort Devens has 17 to 20 vault latrines, which are pumped out twice a year under a contract to pump grease traps and latrines. Total annual cost of the contract is $4000, but there is no breakout for the cost of pumping the latrines alone. The Plans and Training Directorate rents chemical latrines as needed for active duty units. They have an average of two chemical latrines for each active unit. Unit cost is $100 a month; total annual cost is about $1000. The Reserve Component Directorate, which is responsible for leasing chemical latrines for Reserve and National Guard units, spent $6100 for latrines last year. The units are responsible for cleaning the latrines. Odors and vandalism have been a problem. Odors from the vaults are particularly strong at the end of the summer; lime is added to reduce odors. The pumping contractors complain about trash, including ammunition, being thrown in the vaults and interfering with their suction lines.

Fort Dix, NJ

Points of Contact

Mr. Haug, Environmental Engineer, (609) 562-3191

Mr. Gager, Contract Inspector, (609) 562-2449 or 3579

Mr. Buerster, Chief, Management Engineering Systems Branch, (609) 562-2995 or 4445

Composting and Aerated Vault Latrines

At Fort Dix, three 2-year-old Clivus Multrum composting latrines are being used in two buildings. One was built by USA-CERL, and the other by contractors under USA-CERL guidance about 2 years ago. Although the troops and cadre initially feared explosions from high levels of ammonia, they now like the latrines and use them. This points out the need to train personnel who will take care of the latrines, since ammonia is not explosive. The ammonia odors apparently resulted from a nonfunctioning ventilation fan that had been broken for 6 months before it was reported to the Facilities Engineer. Tighter inspection is needed, because people cannot be depended on to report a deficiency, particularly if they don't know how the mechanism works. Range Control is responsible for operating and maintaining composting latrines. If anything malfunctions, Range Control is supposed to call the Facilities Engineer for assistance. FE personnel do not inspect the latrines for proper operation, nor do they check to see if Range Control personnel are performing the required maintenance or reporting any deficiencies. Range Control obtains the bulking agent (sawdust), which is supposed to be added daily, from the FE carpenter shop. A leach field takes excess water from the composting latrines; no water has been noted to accumulate in the latrines.

There are no handwashing facilities at the latrines. The buildings that house the latrines are termed "nice buildings" whose interior walls are made of sheet metal. Vandalism has been minimal, which may be because troops in basic training are under relatively tight control. The latrine seats do not close automatically. There have also been problems with door hinges breaking. Peat moss was used to start up the latrines.

USA-CERL installed ~~aerated~~ vault latrines on an experimental basis. One was aerated by a floating aerator which did not work because trash thrown into the latrines kept plugging up the blades. This aerator was removed after 2 months. The second latrine was aerated by bubblers, which worked well and reduced odors. However, the pumping contractor pumped out this latrine along with nonaerated vaults and thus interfered with the operation.

Other Latrines

There are 55 vault latrines at rifle ranges, bivouac sites, and training areas, but only 37 are in use. The vault latrines are pumped out four times a year; each pumping costs $65. The installation uses an average of 200 to 250 chemical latrines. These latrines are pumped three times per week at a cost of $41 per month. The Commanding General wants to cut the number of vault latrines in half to reduce costs.

Fort Drum, NY

Points of Contact

Mr. Corriveau, Chief, Operations and Maintenance, (315) 785-5311

Ms. Spranger, Engineer Property Office, (315) 785-5517

Composting and Aerated Vault Latrines

One Clivus Multrum composting latrine is now under construction at a new training area.

Other Latrines

The installation uses 108 vault latrines, each consisting of a woodframe building that houses eight commodes and a trough urinal. A contractor pumps them out at a cost of $58 per pumping. About 22 of the chemical latrines used are in fixed positions; the rest are used for active duty, reserve, and National Guard training. These units need an average of 60 to 80 chemical latrines during training from May through August. From April 1984 to May 1985, the installation used 673 chemical latrines at a total cost of $43,291. The unit cost was $35 a month for latrines rented for at least 1 month. The current contract is for $53 per unit per month. The installation also allows units to dig slit trenches and cat holes; however, most troop units prefer to rent chemical latrines, which they rent using their own funds. Some of the latrines have been vandalized and some have been stolen.

Fort Eustis, VA

Points of Contact

Mr. Shifflett, Chief, Environmental Office, (804) 878-2590

Ms. Bradshaw, Environmental Specialist, (804) 878-2590

Mr. Morris, Contracting, (804) 878-3532

Composting and Aerated Vault Latrines

Fort Eustis is not using composting or aerated vault latrines, because the high ground water conditions would preclude their use. They did not consider raising the latrines and putting the composting latrine units at ground level.

Other Latrines

Chemical latrines have been a more flexible solution to providing field latrines, because they can be moved around and increased or decreased according to need. There are 40 chemical latrines at Fort Story (a subpost) and 80 at Fort Eustis. The contractor charges $32 per month for each unit; this price includes weekly cleaning and pumping. The Facilities Engineer keeps five of the 120 units as "floaters" for short-term use. If an organization needs five or fewer latrines, they must pick up and move the latrines themselves. If more than five are needed, the contractor will move them. Some chemical latrines were damaged when they were moved with a forklift, which punched holes in the storage tanks. The latrines are used at picnic areas, ball fields, training areas and ranges, and remote areas where work details are cutting trees or clearing brush.

Fort Gordon, GA

Points of Contact

Mr. Shaffer, Environmental Protection Specialist, (404) 791-7824

Mr. Moore, Chief Sanitation Branch, FE, (404) 791-4148

Composting and Aerated Vault Latrines

Fort Gordon is not using composting or aerated vault latrines.

Other Latrines

Fort Gordon contracts for an average of 275 chemical latrines for use at ranges, training areas, and classrooms not supported by the installation sewage system. They pay $28 per month for units serviced twice a week and $12 per month for units serviced only once a week. Mr. Moore believes the contractor made a mistake in charging only $12 for weekly service, since it is less than half the charge for service twice a week. If a latrine is to be used 24 hours a day, they try to provide one latrine for 12 users. If the latrine will be used only for 8 hours, one latrine is provided for 25 users. This is in accordance with Field Manual 21-10, *Field Sanitation*, which calls for providing latrines for 8 percent of the troops, or one latrine for every 12.5 users. One problem noted at Fort Gordon is that the wind blows the chemical latrines over. Also, it was not clear whether the composting latrines would be classified as new work or as equipment in place. Apparently, composting latrines would be easier to obtain if they are considered to be equipment in place.

Fort Ben Harrison, IN

Point of Contact

Mr. Gray, Chief, Environmental Office, (317) 549-5386

Composting and Aerated Vault Latrines

Fort Ben Harrison--an urban installation primarily supporting the U.S. Army Finance Center--has no ranges or need for remote field latrines.

Other Latrines

The installation contracts for a few chemical latrines for special events such as parades, ceremonies, and other short-term events.

Fort A. P. Hill, VA

Points of Contact

Mr. Wiles, Chief of Utilities, (804) 633-8322

Mr. Wells, Contract Specialist, (804) 633-8260

Composting and Aerated Vault Latrines

Fort A. P. Hill does not use composting or aerated vault latrines.

Other Latrines

The installation uses both chemical and vault latrines. The number of chemical latrines used at any one time range from 10 to 400. The wide range is due to fluctuations

in the number of troop units, both active duty and reserve, that come to Fort A. P. Hill for training and leave after their training is complete. The Boy Scouts separately rent more than 1000 chemical latrines for their National Jamboree, which is held on the installation. The Army is not involved with these rentals.

The Director of Industrial Operations, rather than the Facilities Engineer, manages the chemical latrines. The average leasing cost of chemical latrines ranges from $40 to $50 per month and includes cleaning and pumping twice a week. Septage is taken off post for disposal. The installation also has 136 vault latrines. These are pumped out and cleaned on an as-needed basis. Pumping cost is $80 per latrine. Cleaning is done under a separate contract.

Fort Hood, TX

Points of Contact

Mr. Anderson, Chief, Project Review and Warranty Enforcement Branch, (817) 287-6325

Mr. Spencer, Contracting Officer's Representative, (817) 287-0767

Mr. Stanuszek, Quality Assurance Division, (817) 287-9146

Composting and Aerated Vault Latrines

Fort Hood is not using composting or aerated vault latrines and has not considered using them.

Other Latrines

The installation uses chemical latrines and vault latrines for their remote ranges, training areas, sporting events and ceremonies, and recreational areas. Most ranges have vault latrines. The biggest problem with chemical latrines is coordination between the contractor and the troops. The units sometimes move the latrines after the contractor has installed them, so the contractor cannot find them for servicing or pickup. On the whole, vandalism is minimal; however, some of the latrines have been shot at and run over. Some of the vandalism may result from deer hunters using the latrines for blinds. Fort Hood is an open post so not all vandalism can be blamed on soldiers.

There are 80 chemical latrines in fixed positions. The number of temporary chemical latrines varies a great deal, depending on the training requirements. Last June, during a large training exercise, the installation used 400 latrines. At other times, the number can be as low as 10 temporary latrines. The estimated total cost of chemical latrines for the current year is about $165,000. The contractor charges $2.65 per day, $6.50 per week, or $9.75 per month for rent. There is a $24 delivery fee and a $19 fee for picking up or relocating the latrines, and there is a charge of $4.50 for each servicing. Servicing frequency can vary from daily to weekly depending on the anticipated use.

Installation personnel were unsure of the number of vault latrines they had, but there are probably more than 100. The contractor usually charges $75 for each pumping, but can provide a reduced rate if several vaults need pumping at the same time. Total costs for vault latrines were not available. Each request for pumping is handled as a separate work order. Slit trenches are not prohibited, but apparently are not used often.

Fort Sam Houston, TX

Points of Contact

Mr. Stremel, Chief, Environmental Office, (512) 221-4930

Mr. Moore, Environmental Engineer, (512) 221-4930

Composting and Aerated Vault Latrines

Fort Sam Houston has no composting latrines or aerated vault latrines. They have considered installing several composting latrines at Camp Bullis--a subpost of Fort Sam Houston--but are favoring construction of more vault latrines. They estimate that they can build a vault latrine with eight holes and a urinal for $7500, which is much cheaper than buying Clivus Multrum units. Disposal of excess water from the Clivus Multrums would also pose a problem. Camp Bullis is in the recharge area of the Edwards aquifer, a large limestone formation that is the source of drinking water for San Antonio and the surrounding area. Drain fields are prohibited in this area so sumps or evaporation trays would probably be needed to dispose of excess water from a composting latrine.

Other Latrines

The installation uses both vault and chemical latrines. At Camp Bullis, 29 vault latrines are now in use. During the warmer months, the latrines are pumped in March, May, July, and September. In the cold months, they are pumped only in November and January. Each pumping costs $72; annual cost is about $10,800 for both the regularly scheduled pumping and any extra pumping needed. Current plans are to construct 34 more vault latrines to replace chemical latrines now in use. There are now 31 permanently positioned chemical latrines that cost $42 a month each, including weekly servicing. Additional servicing costs $9.90. Chemical latrines for short-term use cost $29 a day. The Army has 28 chemical latrines at Camp Bullis, and the Air Force has 35. The Army pays $55 per month for each unit, which includes weekly servicing. The Air Force pays only $38 per month for each unit, and the latrines are serviced twice per week. The contracts were negotiated at different times.

Fort Irwin, CA

Points of Contact

Mr. Carroz, Chief Environmental Coordinator, (619) 386-3548

Mr. Foshay, Directorate of Industrial Operations, (619) 386-3891

Mr. McEntire, Directorate of Industrial Operations, (619) 386-3891

CPT Quinlan, Preventive Medicine Officer, (619) 386-3026

Composting and Aerated Vault Latrines

Fort Irwin, which supports the National Training Center, has two composting latrines, but neither is being used. One is in a maintenance area, and the other is in an area where troops are issued equipment. The Facilities Engineer, a contractor, has not hooked them up.

Other Latrines

Most of the chemical latrines used are contracted for by units who come to the installation for training. Others for permanent party use are contracted for by the Facilities Engineer. Range Control personnel inspect the latrines, and all troop units must get clearance from Range Control before they can leave Fort Irwin. The medics inspect only when there are complaints. Some latrines have blown over in the wind, some have been run over by vehicles, and some have been shot at. The use of chemical latrines is irregular, because military units rotate in for 3-week training periods. These incoming units use about 100 to 125 chemical latrines for the first 3 days and the last 3 days when they are processing in and out. For the interim 2 weeks during training, they use only 20 to 30 latrines. The installation also uses 87 chemical latrines in the cantonment area for permanent parties stationed at Fort Irwin. Costs for the training units range from $20,000 to $24,000 per rotation. With 14 rotations a year, the annual cost is $280,000 to $336,000. Costs for the cantonment area are $44,198 for 11 months. Thus, the installation is spending about $360,000 per year for chemical latrines. Assuming about 200 latrines are in use at any one time, the cost is about $150 per unit per month.

Fort Jackson, SC

Points of Contact

Mr. Reyns, Chief, Environmental Office (803) 751-4687

Mr. Stowers, Environmental Engineer, (803) 751-5641 or 4817

Mr. Smith, Chief, Real Property Maintenance and Energy Division (RPME), (803) 751-5641 or 4817

Mr. Varner, Assistant Chief, RPME Division (803) 751-5641 or 4817

Composting and Aerated Vault Latrines

Fort Jackson has constructed five composting latrines. Each is a double unit with four commodes and four urinals and costs about $40,000. The latrines are about 1 year old.

At one range, one latrine is for males and the other for females. The women's latrine handles a lesser load. At the other ranges, the latrines are not designated for specific use by either men or women.

The troops and range personnel like the latrines and appreciate the lack of offensive odors. There has been relatively little vandalism. Some trash has been thrown in the latrines, but it is not considered a big problem. Fire extinguishers have not been used, and there are "no smoking" signs.

The range NCOs are responsible for having bulking agent added to the latrines. A #1 can of bulking agent (sawdust) is supposed to be added to each latrine daily. The sawdust not always added because personnel either forget, or because new range personnel are not told about this requirement. Thus, the high turnover in range personnel is a continuing problem for keeping the latrines in optimal condition.

The troops get the sawdust from the carpenter shop. They have had some matting problems with the sawdust, which was described as medium-coarse. They probably use what is given to them, and there does not appear to be any effort to select wood chips or shavings, which would be better bulking agents.

The Facilities Engineer range maintenance personnel periodically check the latrines, but there is no established inspection schedule. The medics are reportedly not inspecting the latrines.

There have been problems with the ventilation fans shutting down because of low voltage. The voltage varies more than usual because the latrines are at the end of the power line.

The doors and walls are constructed of particle board, and there have been problems with hardware such as door hinges screwed into the board which easily tore out. The screws were replaced with bolts and metal plates.

Fort Jackson has also put in aerated vault latrines. Mr. Reyns prefers them to the composting latrine, since they are less expensive. He said it costs $1100 to $1900 to retrofit vault latrines with aerators.

Other Latrines

The installation is also using vault latrines with and without bottoms and chemical latrines. There are 345 chemical latrines in use at an annual cost of about $106,000. Unit costs include $12 per month for rent, $38 per month for servicing three times a week, and $12 for moving the latrines. Only one person bid on the contract; although this contractor was local, the needed servicing is sometimes not done.

Fort Knox, KY

Points of Contact

Mr. Smith, Environmental Office, (502) 624-4654

Mr. Thomas, Work Order Section, (502) 624-2953

Mr. Fowler, Estimating Office, (502) 624-7346

Ms. Ault, Procurement Division, (502) 624-7753

Composting and Aerated Vault Latrines

Fort Knox is not currently using composting or aerated vault latrines, but they are planning to install a composting latrine at one site. They will probably use Clivus Multrum. One unit being investigated has one commode for men and two for women, and costs about $50,000.

Other Latrines

Fort Knox uses vault latrines. Although Mr. Smith believes that they leak, inspection last fall showed them all to be dry at that time. There have been many complaints about odors from the latrines.

Fort Knox uses about 40 permanently placed chemical latrines, which cost $37.50 per month per unit. These latrines are serviced weekly. Other chemical latrines are obtained on an as-needed basis and cost $55 per month. This rate applies even if the unit is used less than a full month. Total cost last year for chemical latrines was about $32,000. Overall, service is considered good.

Fort Leavenworth, KS

Points of Contact

Mr. Burns, Environmental Engineer, (913) 684-5441

Mr. Yelton, Contracting Specialist

Composting and Aerated Vault Latrines

Fort Leavenworth does not use composting or aerated vault latrines.

Other Latrines

This installation, which supports the U.S. Army Command and General Staff College and houses the Disciplinary Barracks, has no ranges and therefore has limited need for remote site latrines. They do use about 26 chemical latrines at special events and in remote areas for Disciplinary Barracks work details. The latrines are obtained under contract at $27.50 per month. This price includes weekly cleaning and pumping. A reserve unit, HQ, 35th Mechanized Infantry Regiment, is trying to establish a training area near the Missouri River. If this is approved, field latrines would have to be built.

Fort Lee, VA

Points of Contact

Mr. Beatley, Environmental Engineer, (804) 734-4254

Mr. Allen, Contracting, (804) 734-1401 or 4562

Composting and Aerated Vault Latrines

Fort Lee is not using composting or aerated vault latrines. The Facilities Engineer prefers to connect all latrines, including field latrines, to the sewage system or septic tanks. Since Fort Lee is a relatively small installation with limited needs for field training, this policy works well for them.

Other Latrines

Fort Lee uses about six chemical latrines that remain in permanent positions. The contractor charges $30 per month to lease each unit; this cost includes servicing the latrine weekly. The installation also leases about 200 latrines over a 1-year period for temporary or short-term use. These latrines cost $40 per month. If the latrines must be serviced more than once a week, the contractor charges $10 for each additional servicing. The installation has no vault latrines. Slit trenches and other field expedients are permitted on a limited basis for training purposes.

Fort Lewis, WA

Points of Contact

Mr. Hanke, Sanitary Engineer, (206) 967-5461

Mr. Miller, Environmental Office, (206) 967-5646

Composting and Aerated Vault Latrines

Fort Lewis has no composting latrines or aerated vault latrines. Mr. Hanke is familiar with composting latrines and would like to install some at Fort Lewis and its subposts. They are considering use of composting latrines at the Huckleberry Creek Mountain Training Area and at the Yakima Firing Range. The high cost of the Clivus Multrum units has been the prime factor in not getting them approved. They are also concerned about the potential for vandalism, particularly in remote areas where there is no close supervision. Mr. Hanke said he would be very interested in a design that in-house workers or a contractor could use to build a composting latrine.

Other Latrines

Fort Lewis is using field-expedient latrines, slit trenches, cat holes, chemical latrines, vault latrines, and pit latrines. They have ten 1000-gal vault latrines. Each is a two-holer with a wind-driven exhaust fan. A contractor services these vault latrines quarterly at a cost of $350 per servicing. Fort Lewis uses about 500 chemical latrines at Fort Lewis and from 250 to 350 at the Yakima Firing Range. The major use is for ROTC summer training. The ROTC does not like to use pit latrines or other field-expedients. Chemical latrines are also used in the cantonment area, in heavily used training areas, and on land leased for training. The owners of leased land insist on chemical latrines since they do not want pit latrines dug on the land.

The contractor charges $87 to install each chemical latrine, $0.75 per day for rent, and $8.75 for each servicing. The total annual cost is about $70,000 for ROTC training and $35,000 for other uses. Mr. Hanke would like to buy 500 chemical latrines for Fort Lewis and contract just for the servicing. The cost of an unassembled chemical latrine is about $450 per unit. If assembled, they cost about $550 a unit.

Fort McClellan, AL

Points of Contact

Mr. Owens, Chief, Land Management Branch, Building and Grounds Division, (205) 238-3609

Ms. Sefcik, Contract Specialist, Procurement (205) 238-4318

Composting and Aerated Vault Latrines

Fort McClellan is not using composting or aerated vault latrines.

Other Latrines

Chemical latrines are used throughout the installation at ranges and recreation sites. They are also used for special events such as parades and ceremonies. The Facilities Engineer is responsible for the chemical latrines. Fort McClellan uses an average of 368 chemical latrines per month. Cost is $14.95 per month for each unit, plus $2 per servicing. The units are serviced twice each week. If units are used less than a month, cost is $10 per day per unit. If a unit is destroyed, the Army must pay $750 for a replacement. Fort McClellan has no government-owned units. At least two latrines have been burned--one by vandals and the other from a range fire. There have been no other significant problems. Two vault latrines are in use at recreation sites at Yakou Lake and Lake Riley. The troops are permitted to use cat holes and slit trenches at selected sites. Prior approval must be obtained from the Facilities Engineer.

Fort McCoy, WI

Points of Contact

Mr. Starck, Environmental Office, (608) 388-2308

Mr. Olson, Chief, Operation and Maintenance, (608) 388-3051

Ms. Heuer, Procurement Agent, (608) 388-3203

Composting and Aerated Vault Latrines

Fort McCoy is not currently using composting or aerated vault latrines, but they are considering use of composting latrines.

Other Latrines

The installation is using chemical latrines, slit trenches, and vault latrines. The number of chemical latrines used varies widely with the number of military units that are training. The installation spends an estimated $15,000 per year for chemical latrines at a unit cost of $20 per week with one servicing weekly. The $20 is a minimum and applies even if a latrine is rented for only a day. Any extra servicing costs $10 and an extra move costs $16.

The contractor is providing adequate support. The only problem identifed was some damage that occurred when troops tried to move the latrines with a forklift.

Personnel are unsure of the number of vault latrines on the installation, but estimate there are about [illegible]0.

Fort Meade, MD

Point of Contact

Mr. Kitteger, Chief of Operations, (301) 677-4444

Composting and Aerated Vault Latrines

Fort Meade is not using composting or aerated vault latrines.

Fort Monroe

Point of Contact

Mr. Logan, General Foreman, Public Works Division, (804) 727-2488

Composting and Aerated Vault Latrines

Fort Monroe has no composting or aerated vault latrines. It is a small installation occupied by the U.S. Army Training and Doctrine Command headquarters. They have no ranges or remote sites where composting or aerated vault latrines would be useful.

Other Latrines

Fort Monroe uses a small number of chemical latrines for special events and construction projects.

Fort Ord, CA

Point of Contact

Mr. Cochran, Chief, Environmental Office, (408) 242-4505

Composting and Aerated Vault Latrines

Fort Ord and its subposts at Fort Hunter Liggett and Camp Roberts do not use composting or aerated vault latrines.

Other Latrines

The installation uses chemical and vault latrines at Fort Ord, Fort Hunter Liggett, and Camp Roberts.

Fort Pickett, VA

Points of Contact

Mr. Foley, Chief, Environmental Office, (804) 292-2630 or 8577

Mr. Upson, Facilities Engineer, (804) 292-2630

Composting and Aerated Vault Latrines

Fort Pickett is not using composting or aerated vault latrines.

Other Latrines

The installation is using 96 vault latrines and an unknown number of chemical latrines. The vault latrines are pumped as needed and cost about $14,000 a year. The number of chemical latrines could not be estimated because of the wide variation in training requirements. The estimated annual cost of chemical latrines is $50,000.

Fort Polk, LA

Points of Contact

Dr. Stagg, Chief, Environmental Division, (318) 535-6260

Mr. Nelson, Chief, Range Maintenance, (318) 535-4887

Ms. Sherrill, Contracting Specialist, (318) 535-6510

Composting and Aerated Vault Latrines

Fort Polk is not using composting latrines. Although they considered using them at Toledo Bend, a recreation area, they decided against it, mainly because they were concerned about misuse and vandalism. Flush latrines were installed instead; treatment is by oxidation ponds.

Other Latrines

Fort Polk is using vault latrines and chemical latrines. They also allow limited use of cat holes and slit trenches, but only on land owned by the Army. The installation also uses about 100,000 acres of U.S. forestland for training, but is prohibited from digging latrines. The use of field-expedient latrines at Fort Polk is governed by Technical Bulletin 10, Fort Polk Regulation 420-12, and Army Field Manual 21-10, *Field Sanitation*. Contractors have complained about troops throwing trash and foreign objects such as live ammunition, which plugs up their suction lines, into the vault latrines. Fort Polk is currently spending $2780 a year to lease and service 34 chemical latrines. The unit price is $81.76 a week, which includes three servicings per week.

Fort Riley, KS

Point of Contact

Mr. Kosovich, Engineering Division, (913) 239-9549

Composting and Aerated Vault Latrines

Fort Riley has one composting latrine located at an old Hawk Missile maintenance site. The Facilities Engineer and some troop units now use the site as a maintenance facility. The unit is believed to be 3 to 5 years old. The composting latrine is located in a separate building and serves about 30 civilian and 15 military personnel. The latrine has three composting latrines in a vault below the building, each of which supports two commodes. An interior wall separates the side used by Facilities Engineer personnel from the side used by troops. There are probably drains that lead to a sump with a sump pump. Mr. Kosovich is not sure where the drainage is pumped and thinks it may go to a leach field for the septic tank at a nearby Military Affiliate Radio System (MARS) radio station. The users are not enthusiastic about the latrines.

Six lavatories were originally installed, but only with cold water. When the FE took over the units, hot water was provided.

It is estimated that bulking agent (wood chips and shavings) is added every 3 months. The ventilation fan is line-operated, but its size is unknown. The lights are

fluorescent fixtures. Urinals are stainless steel, 12 to 16 in. long, that hang on the wall. Interior ventilation is provided by three screened windows which can be opened. The interior walls are built of cinder block, and the floor is concrete. There are two floor drains.

Access to the composting latrine units is by ladder. All units are in one vault and there is plenty of room to work in. There are some flies during the summer, but they are not a serious problem. No one inspects the units regularly, including the medics. There has been no vandalism, probably because the latrines are used mainly by the same people.

Fort Rucker, AL

Point of Contact

Mr. Hayes, Chief of Utilities, (205) 255-3837

Composting and Aerated Vault Latrines

Fort Rucker is not using composting or aerated vault latrines, and has not seriously considered building them. Since the installation's principal activity is helicopter training, and the ranges are seldom used by ground troops, there is little need for remote site latrines. However, the National Guard does do some training there during the summer months.

Other Latrines

The installation has an estimated 12 to 15 vault latrines for range latrines. These are pumped out by Facilities Engineering personnel as needed. It is estimated that each is pumped once a month during the summer when the latrines are most heavily used. The Range Control Office notifies the FE when they need to pump the latrines. Range personnel keep the latrines clean and supply toilet paper. The vault latrines are pumped by the plumbing shop, and cost figures were not available. They do not use chemical latrines.

Fort Sill, OK

Points of Contact

Mr. Anschutz, Chief, Environmental Division, (405) 351-2715

Mr. Cain, Chief, Environmental Protection Branch, (405) 351-2715

Mr. Lewis, Chief of Utilities, (405) 351-5341 or 3608

Composting and Aerated Vault Latrines

Fort Sill's principal means of handling human waste at remote sites is by unlined pit latrines, which is thought to be the most effective and least expensive method. State environmental authorities have not objected. The installation owns and uses between 80 and 90 chemical latrines, but they are phasing them out through attrition. Fort Sill obtained the chemical latrines from Fort Chaffee, which used the latrines at the Viet Nam refugee camp in the 1970s. Fort Sill only paid the charges for shipping them from Fort

Chaffee. They have experienced a lot of vandalism; latrines have been set on fire, run over with vehicles, and shot at. High winds have also blown them over.

The installation also has six timber-lined vault latrines; however, pumping them has been difficult because of the excessive amounts of trash thrown into them. The costs of pumping the chemical and vault latrines could not be identified. The installation has one large contract to pump septic tanks, grease traps, and latrines, but the cost for pumping the latrines is not broken out as a separate line item. They have no plans to buy new chemical latrines. When all the chemical latrines now in use are phased out, new ones will be rented as needed.

Fort Stewart, GA

Points of Contact

Mr. Keffer, Chief, Environmental Branch, (912) 767-2010

Mr. DeLoach, Environmental Specialist, (912) 767-2010

Ms. Stricklen, Contracting Division, DIO, (912) 767-8461

Mr. Hausten, Chief, Buildings and Grounds, (912) 767-4794

Composting and Aerated Vault Latrines

Fort Stewart is not currently using composting or aerated vault latrines. However, because of the high ground water conditions underlying much of the installation, composting latrines may be an attractive choice for remote sites.

Other Latrines

Fort Stewart leases 130 chemical latrines: 80 at Fort Stewart and 50 at Hunter Air Field. The contractor charges $25 per month for each latrine, $17 per month for servicing them twice a week, and $11 to relocate a latrine. For short-term rentals, the contractor charges $40 per day. The installation has had some problems with getting the contractor to maintain the latrines. Complaints of odors usually result from poor contractor maintenance. There have been several incidents in which soldiers have pushed the latrines over or run over them with vehicles. Fort Stewart also uses pit latrines built into mounds because of the high ground water.

APPENDIX C:

VAULT LATRINES: DESIGN AND MAINTENANCE CONSIDERATIONS*

Vault latrine designs present numerous maintenance and operational challenges. This appendix outlines some of the problems with servicing a vault latrine at a Forest Service site and some design and maintenance considerations that may reduce these problems.

Is the Pumper Properly Equipped?

Description

Many commerical sewage pumpers have 2-1/2-in. hard rubber suction hoses that taper to 2-in. metal ends. An on-off suction valve is often located at the truck. Although this equipment can be operated by one person, two operators are better. When the hose becomes clogged, an operator standing at the truck can clear the end of the hose.

Some commercial sewage pumpers have 4-in. hoses. The 4-in. opening facilitates removal of cans, bottles, and fairly large rags if the pumper is using the vacuum principle. However, if the cans, bottles, and other debris are pumped from the vault into the truck tank, the pumper operator has a disposal problem. Sewage treatment plants will usually not accept this inorganic material.

A rake, a hoe, and a garbage can lined with a plastic bag should be available near the pumping operation. The rake, which should have at least four tines about 4 in. long, can be used to remove the miscellaneous debris. The hoe is needed to stir the vault contents immediately before pumping, and the waste container will hold material removed with the rake.

If a waste container is placed right next to the latrine building's entrance, it may reduce the amount of the debris thrown into the vault and thus lessen the amount of debris that must be removed during pumping.

Recommendations

The open end of the suction hose should be at least 3 in. and preferably 4 in. wide; the hose should be the same size as the open end.

If the commercial pumper operator discharges the waste at a treatment plant and has no means to dispose of cans, bottles, and other debris after they are in the truck tank, as much as possible of the miscellaneous debris should be removed before vault pumping begins. The rest can be removed after pumping.

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*Excerpted from *Vault Toilets...Design and Maintenance Considerations* (U.S. Forest Service, February 1976).

How Should the Vault Access Cover Be Shaped and Where Should It Be Located?

Description

Access covers at existing vault latrines vary in shape, size, and location. The following sections describe some of the designs and problems.

Pumping Through the Latrine Seat Riser Hole (With Riser Removed). It is difficult for the pumper operator to maneuver when using a hose, rake, or hoe in small latrine building compartments. When the hose becomes clogged, the operator must lift the hose from the vault and, after turning off the suction valve at the truck, must place his/her foot on the object clogging the hose and lift the hose. The sewage immediately behind the clog then pours over the floor surface and the operator's foot. Also, the hose usually is rubbed against the wall during this process, depositing fecal matter and debris on it. By the time the operator finishes a very normal pumpout, the floors and lower walls are heavily contaminated. If the floors or walls are porous, odors remain for a long time and people, especially those who are barefoot, are subjected to very unsanitary conditions. A typical vault latrine riser hole is about 18 by 22 in. If it is necessary to enter the vault, the space will accommodate only a small person.

Pumping Through an Access Cover Located in the Front Entranceway. This location produces the same results noted in the previous section. Most front entranceways are unsealed concrete and very porous. Having the access cover in this location places it opposite from the concentrated waste, which makes the waste difficult to remove. Also, some buildings have a privacy screen in front of the entrance doors. Trying to maneuver between the building and privacy screen with long-handled tools is awkward.

If the cover is not gasketed, odors rising around the cover can be offensive to users. During the normal cleaning, dirt and debris are either swept from the building or washed out the front door and end up on the access cover. Some of this contaminated material may fill the space around the cover and be a source of odor. When a gasketed cover is opened to clean the vault, the gasket area has to be cleaned thoroughly if the cover is to be resealed and odors prevented. Even if the access cover is of adequate size for easy entry, the location presents too many problems.

Recommendations

The access cover should be at least 24 in. wide or in diameter and be located immediately to the rear or side of the building, whichever is closer to the vault latrine riser. Generally, the flow of traffic is not past the rear of the building; therefore, if the areas right next to the access cover did become contaminated, few people would be exposed to them.

The cover should be round because it is impossible to drop a round cover through the opening. If the cover is square or rectangular, it should be hinged so that the cover rises toward the building. The cover should be locked for public safety.

How Deep Should the Vault Be?

Description

Vaults are 4 to 10 ft deep. The difficulty of cleaning a vault increases with depth. Most commercial pumpers use flexible hose at the suction end of the pumping line. As

vault depth increases, it becomes more difficult to maneuver the hose. Consequently, the hose may be dropped in and remain in one area. Most, if not all, of the water portion of the waste is removed within the first few minutes. If no more water remains, the pumper can do little more than remove a portion of the sludge by moving the hose (with difficulty) within the vault.

Removing large objects (for example, 30- to 70-lb rocks) from deep vaults is difficult because the leverage point is too far from the object (the pumper is attempting to work from the outside of the vault). The best way to remove large objects is to enter the vault and remove them by hand. The deeper the vault, the more reluctant the pumper operator is to enter it; also, the deeper the vault, the greater the chance of deoxygenation. Therefore, precautions should be taken to ensure that the operator has sufficient oxygen when he/she is in the vault.

If the vault is 6 to 8 ft deep, the operator must have a rake at least 7 to 9 ft long to remove miscellaneous debris. It is difficult to balance this debris when lifting it out of such a deep vault. The difficulty increases when the operator is confined within a building compartment or in the front entrance area.

Recommendations

The vault should be about 4 ft deep. This will allow the operator to remove the debris easily and maneuver the hose easily for greater sludge removal; also, if it is necessary for the operator to enter the vault to remove a large object, it will not be too unpleasant. If the vault is less than 4 ft deep, the waste quickly builds up close to the user area and causes aesthetic problems.

What Volume Should the Vault Be?

Description

Vault capacities vary from 55 to 1200 gal. The vault latrines are inspected to determine which ones need pumping; depth of the waste below the floor line is a major factor. In many cases, the inspector has never seen the bottom of the vault, and no list is immediately available to indicate how deep the various vaults are.

Some vaults have not been pumped for many years. If a vault is not cleaned thoroughly each year, miscellaneous debris builds up and bridges the waste within about a year. Then the vault may be difficult to clean and often get cleaned only down to the debris level. Although there may still be a few feet of fecal matter remaining, the debris will prevent further normal pumping procedures.

Vault pumping contracts vary; the three most common methods of contracting are:

1. Vault: the contractor receives the same compensation, regardless of vault size.

2. Hourly: the contractor is paid from the time of departure from his/her place of business until return to point of origin.

3. Gallon: the contractor is paid according to the number of gallons pumped from each vault.

If the contractor receives the same compensation for each vault, regardless of its size, it would not be cost-effective to limit the size of a vault in a heavily used recreation area that might require more than one pumping per season.

Recommendations

The size of each new vault latrine should be determined based on how often it will be used. For example, when a 1000-gal vault only receives 250 gal of waste, it is more difficult to clean because the waste is dispersed. The vault should be no more than 4 ft deep; in most cases, a capacity of 500 gal will be sufficient. Each vault should be cleaned *thoroughly* each year.

How Should Vault Waste Be Removed?

Description

The operator has two options:

1. Use a rake or hoe to remove cans, bottles, rags, clothing, and other miscellaneous debris prior to pumping. The debris can then be placed in plastic bags and hauled away as solid waste. A 3- to 4-in. hose can then be used to remove the waste. A small hose (2 to 2-1/2 in.) is easier to handle, but is more susceptible to clogging.

2. Use a 4-in. or larger hose to remove the waste and miscellaneous debris.

Many treatment plant operators will not accept the type of debris often thrown into the latrines, so it must be removed from the waste when the pumper is discharged. Other larger debris, such as logs and rocks, cannot be pumped and must be removed by hand.

The Forest Service has designed some vault waste dump stations, which are concrete manholes that have slanted or horizontal bar screens to remove miscellaneous debris. This method has achieved varying degrees of success. If the bars are too far apart, plastic bags and large rags are able to pass through. In aerated-lagoon treatment, these items jam the aerator impellers. If the bars are too close together, the screen must be cleaned every few minutes.

Recommendations

Regardless of how the vault is pumped and cleaned, the problem of miscellaneous debris must be solved. Use of proper tools makes it easier to remove this debris prior to pumping. To facilitate removal of debris from vaults of varying depths, operators should have rakes and hoes that have adjustable handles. The waste should then be pumped with 3- to 4-in. hoses.

A 4-ft-deep vault reduces problems associated with excavation, the water table, and earth presure against the vault sides. Concrete block can be used to support the synthetic rubber vault latrine liner. (Hypalon is recommended as a good liner.) With a 45-mil, nylon-reinforced Hypalon, only a sand bottom is necessary for the liner. About 3 to 4 in. of concrete should be poured into the liner to prevent the liner from puncture by glass, rocks, logs, and pumper hoses. More concrete may be needed to prevent uplift from a high water table. The liner should be attached to the upper concrete block wall by 1- by 3-in. treated boards; the boards are attached to the wall by screws, which are

placed into lead inserts. The liner is therefore between the wall and the boards. Metal grommets are evenly placed around the top lip of the vault liner during factory fabrication.

The floor surface of the vault should be sloped 1 in. per foot toward the outside access cover; 5 in. from the Hypalon support, the slope should end to become a flat level plane for the last 6 in. The flat surface will allow the sewage suction hose close access to the bottom of the vault to provide more effective waste removal.

An alternative to the Hypalon liner is a rigid cross-lined polyethylene container. It is not necessary to pour concrete into the container; however, in high water table areas, a sand bedding should be placed under the container. The container should be secured to the concrete block walls as described above for the Hypalon liner. If a concrete slab were placed over the top of the container, no securing would be necessary. The cross-lined polyethylene container can be designed to be buried without additional support.

A 45-mil nylon-reinforced Hypalon liner of 500-gal capacity costs about $120, and a cross-linked polyethylene container of 500-gal capacity costs about $200. The container to be buried without support is projected to cost $300. Detailed information on procuring these or larger-capacity liners and containers is available from the following manufacturers:

1. Hypalon Liner:

   Burke Rubber Co.
   2250 S. Tenth Street
   San Jose, CA 85112
   Telephone: 408-297-3500

2. Polyethylene Container:

   Hollowform, Inc.
   6345 Variel Avenue
   Woodland Hills, CA
   Telephone: 213/884-0949

Should Vaults Be Cleaned After Pumping, and If So, How?

Description

When the level of waste is lowered by pumping, small waste particles will adhere to the sides of the vault, even if the walls are cross-linked polyethylene or synthetic rubber. When exposed to oxygen, these small particles will generate considerable odor. The particles will soon dry and stick to the wall surface. During subsequent pumpings, more particles will adhere to the particles already on the wall. The concrete and concrete block vaults now in use are impossible to clean thoroughly because they absorb odors. Also, concrete tends to crack, which allows the liquid to seep away and makes pumping difficult.

Recommendations

The vault walls should be hosed down with a pressure hose and, if possible, scrubbed with a long-handled brush. The extra water should then be pumped out. If the vault floors slope 1 in. per foot, the washdown water will flow to the low end making it easier to remove. When as much waste and washdown water as possible are removed, fresh water should be added to cover the bottom floor surface of the vault.

For a vault sloped at 1 in. per foot, with dimensions of 5 ft long, 4 ft deep, and 3-1/2 ft wide (about a 500-gal capacity), it will take about 30 gal to cover the entire

bottom surface. This added water will help dilute the remaining waste and help prevent the fecal matter from forming a cone.

Should Vault Latrine Building Floor Surfaces Be Cleaned?

Description

Floor surfaces in vault latrine buildings range from particle-board to concrete. These surfaces harbor bacteria, which create unpleasant odors and unsanitary conditions.

Recommendations

All floor surfaces should be sloped slightly to the front and should be sealed *completely* so that the flooring material will not absorb wastes.

Should Chemicals Be Used To Control Vault Odors?

Description

Chemicals are used mostly to help control odors in poorly vented vault latrines. However, consideration must be given to the eventual means of waste treatment and whether chemical additions will hinder these processes. For example, in one case, about 3000 gal of vault waste that contained odor control chemicals sterilized a 110,000-gal aerated lagoon.

Recommendations

Generally, chemicals should not be used to control vault odors. The building's venting system should first be analyzed. If it is impossible to reduce odors by improving venting, only formaldehyde-based chemicals or space deodorants should be considered and amounts recommended by the manufacturer should not be exceeded. Formaldehyde will biodegrade with sufficient dilution.

Odors also emanate from porous walls and floors in poorly maintained older buildings. Therefore, building interiors should be cleaned often with a disinfectant deodorant-type cleaner.

Summary

A vault designed to reduce maintenance and odor should have the following:

1. A minimum 24-in.-diameter, round access cover located immediately behind or to the side of the building.

2. A maximum capacity of 500 gal unless, after analysis, it is determined that a larger capacity is warranted.

3. A depth of approximately 4 ft.

4. A vault bottom sloped 1 in. per foot toward the access cover, except that the last 6 in. should not be sloped but be a flat, level plane.

5. An impervious liner to prevent seepage (in or out), and to make it easy to clean after pumping (45-mil reinforced Hypalon or cross-linked polyethylene is recommended). After cleaning, enough water should be added to completely cover the bottom of the vault to help dilute the waste and help prevent the fecal matter from forming a cone.

6. No odor-control chemicals if they will hinder the final treatment process; proper venting will take care of most odor problems.

7. All walls and floor surfaces in the building use area properly sealed and the floor sloped to the front for easier cleaning.

8. Waste containers permanently located immediately adjacent to latrine entrances.

APPENDIX D:

AERATED VAULT CONSTRUCTION AND INSTALLATION

Plumbing Parts
(In-vault network)

3/4-in. PVC

Two 10-ft sections
1 elbow
1 tee
3 PVC to cast iron couplings

3/4-in. cast iron

Four 12-in. nipples
4 caps
Two 4-in. nipples
2 tees

Additional Plumbing Components

3/4 in. cast iron nipples and elbows for connecting piping network to motor/blower unit (site-specific).

Assorted Electrical Components

Romex
Conduit
Wire nuts
Boxes
Well-equipped electrician's tool kit

Motor/blower Unit Installation Components

Concrete pad
Lag bolts and anchors
Rubber hose
Hose clamps
Lock
Rubber pad

Recommended Optional Components

6-in. fan and PVC vent stack
Well-equipped tool kit with a variety of plumber's, carpenter's, and electrician's tools

Step 1

Measure length of vault. Subtract 6 in. to allow flexibility and ease of movement. Cut one section of 3/4-in. PVC pipe to length. Drill 1/8-in. holes completely through PVC every 2 in. Make sure that the drilled holes are in two parallel lines (Figure D1).

Step 2

Form legs of piping network (Figure D2). Always use teflon tape at joints involving cast iron and tighten. Attach one 12-in. cast-iron nipple on each end of a 3/4-in. cast-iron tee (Figure D2).

Attach caps on ends of nipples (Figure D2).

Attach 4-in. nipple on open end of tee (Figure D2).

Repeat so there are two sets of legs.

Step 3

1. Attach 3/4-in. cast iron to PVC adaptor (made of PVC) to each leg set (Figure D3).

2. Attach 1-in. lengths of PVC on each leg using PVC glue (Figure D3).

3. On one leg, attach PVC elbow perpendicular to the direction of the legs, using PVC glue (Figure D4).

4. On the other leg, attach the PVC tee perpendicular to the direction of the legs using PVC glue (Figure D4).

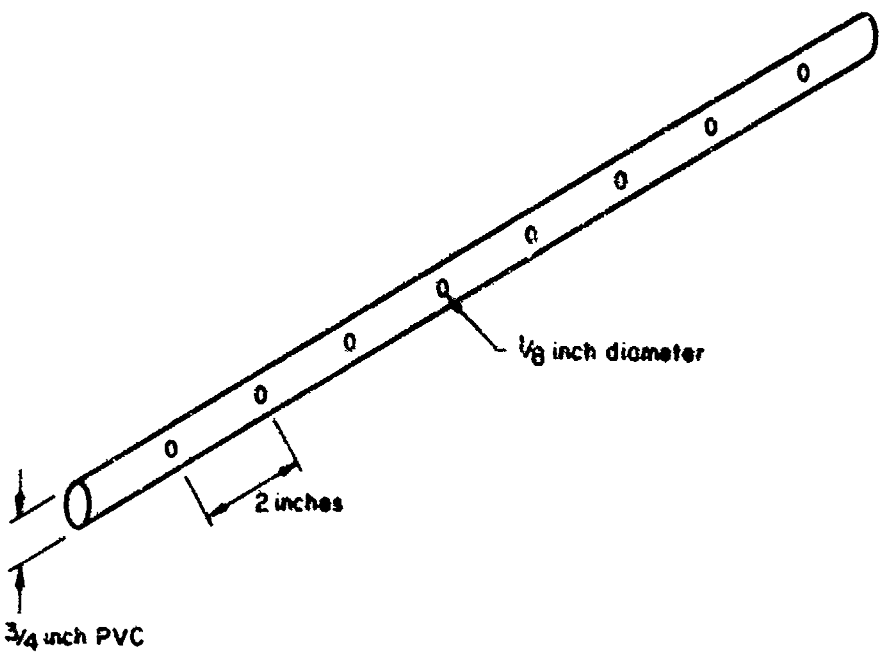

Figure D1. Perforated PVC pipe.

All 3/4" C.I. (Cast Iron)

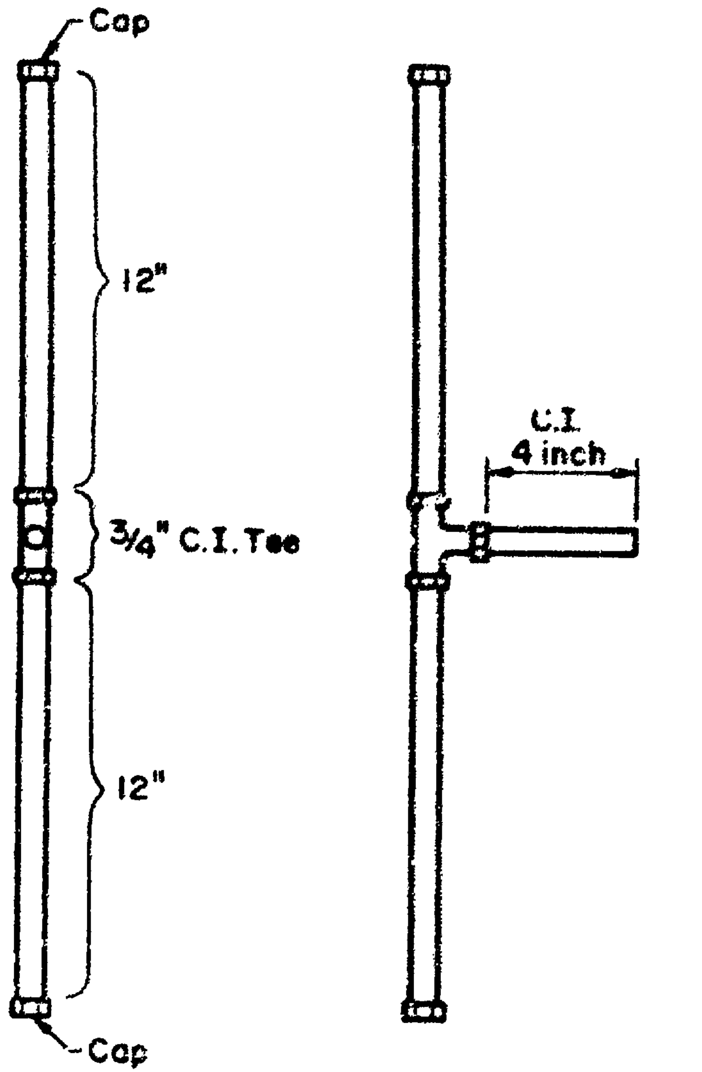

Figure D2. Construction of typical leg.

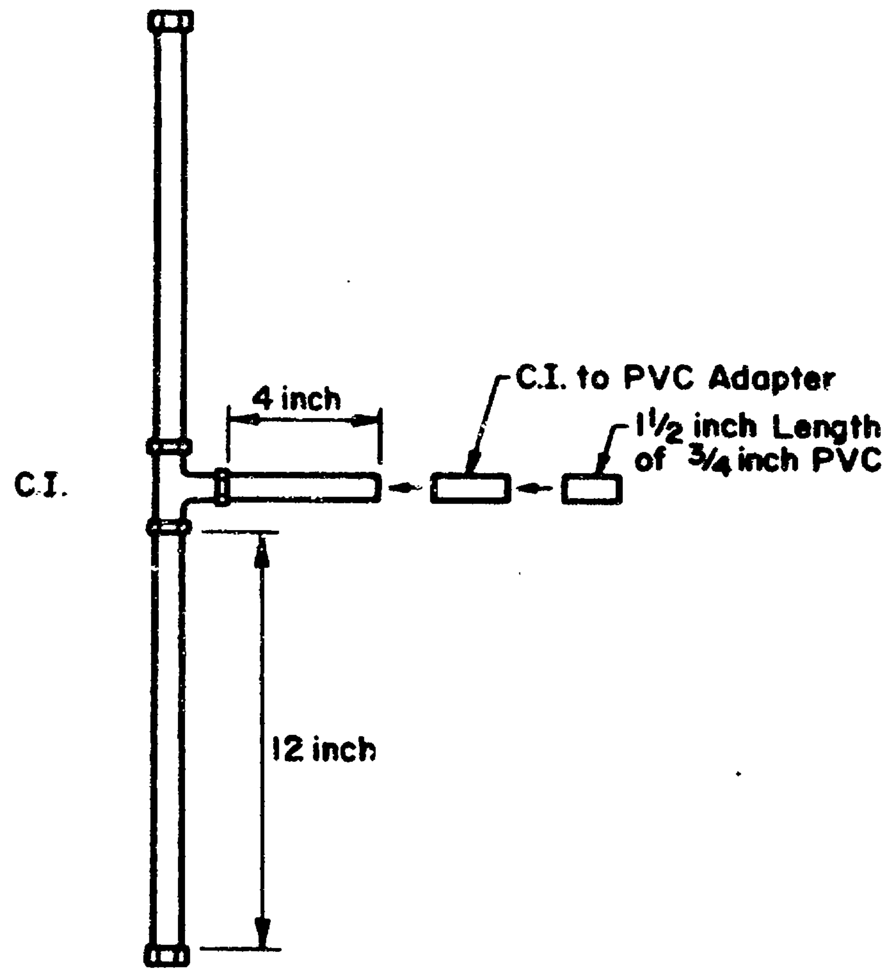

Figure D3. Connection of cast iron to PVC.

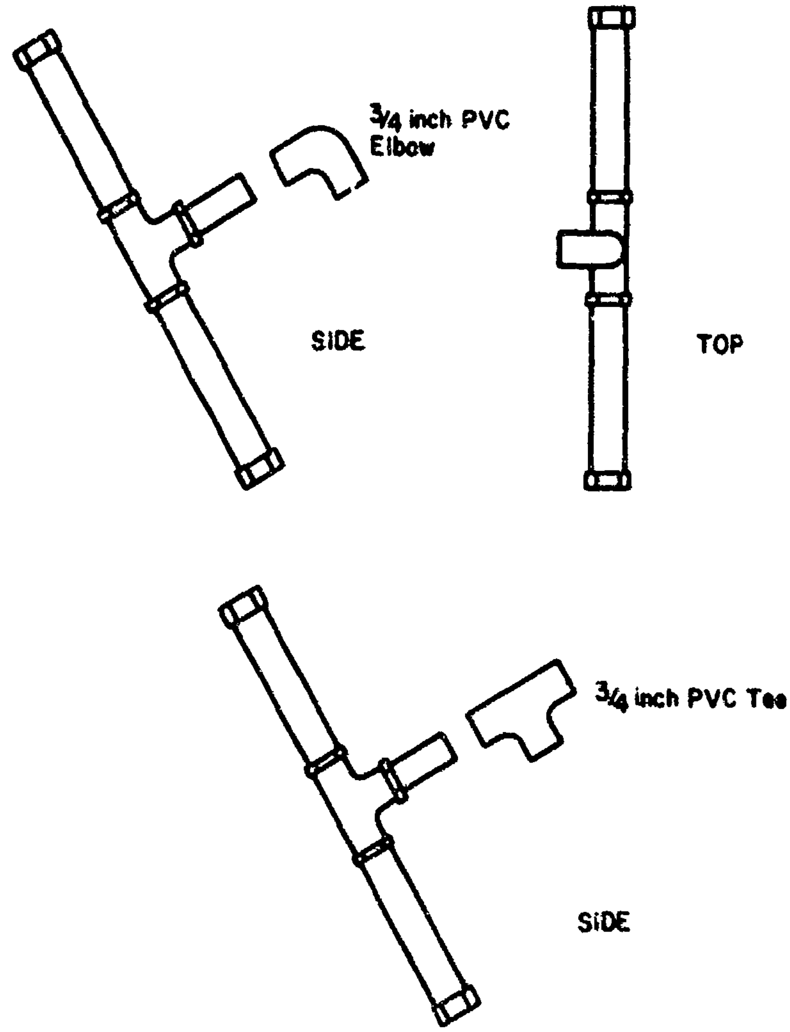

Figure D4. PVC connections from legs.

Step 4

1. Connect "cut to length" piece of PVC pipe with holes parallel to ground (horizontal) to both leg sections (Figure D5).

2. Glue the other 10-ft section of 3/4-in. PVC to the pipe network to stand vertical (Figure D5). To provide more flexibility, this step may be delayed until installation within the latrine box (see Steps 6 and 7.)

Step 5

Prepare area on the side of the building to hold the prefabricated motor/blower unit (Figure D6). Usually this will be on the outside side of the building near the manhole or entrance to the vault. When the box is centered in the building, improvisation with wiring and plumbing will be necessary. This site should be level and provide a strong surface to anchor the motor/blower unit. USA-CERL has used existing concrete slabs (preferred) as well as concrete blocks and patio slabs for this purpose. Also, try to avoid placing the unit low to ensure that runoff stormwater does not interfere with the unit.

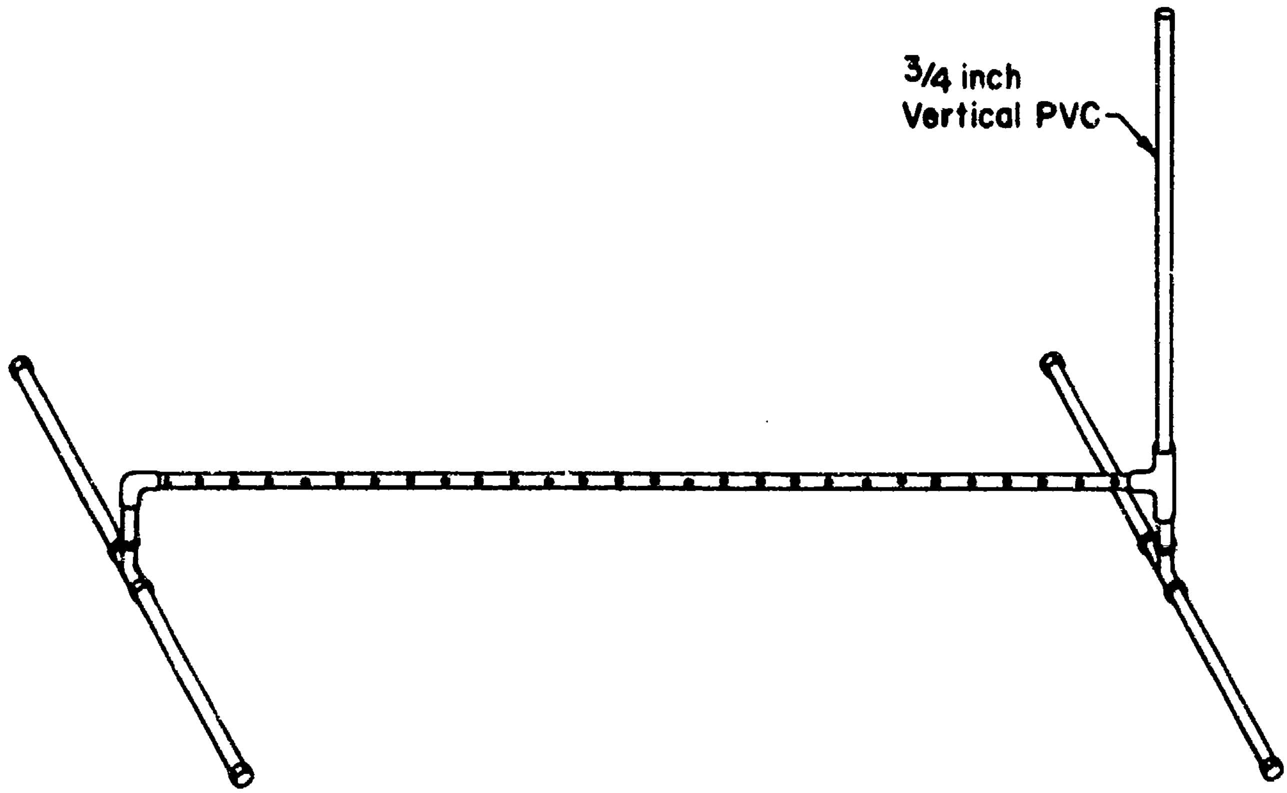

Figure D5. Assembled in-vault piping network.

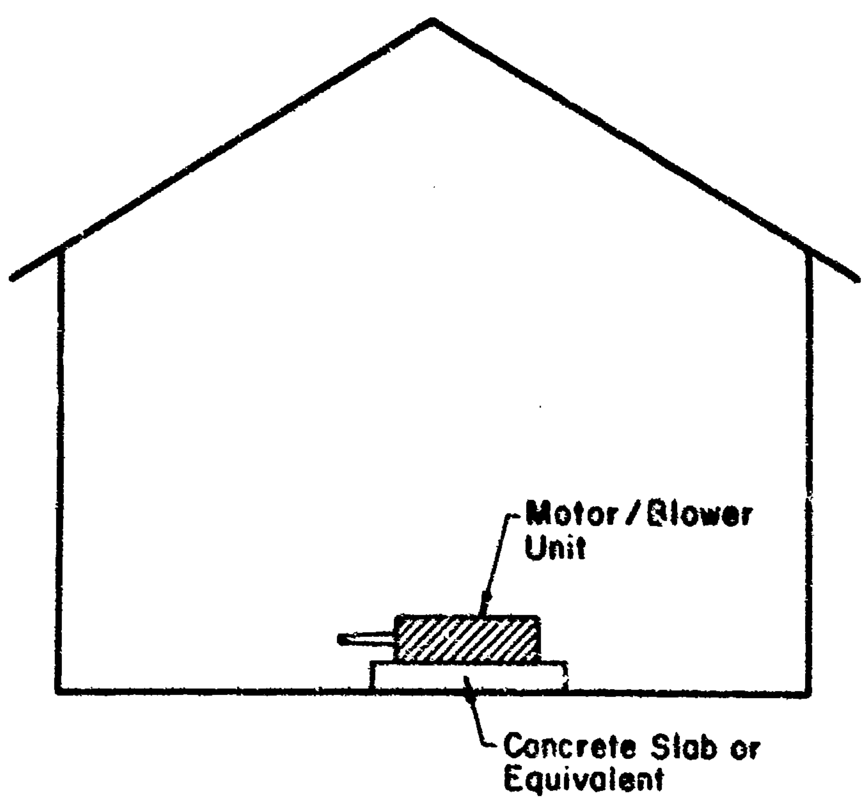

Figure D6. Motor/blower unit placement.

Step 6

From here on, installers must be flexible.

Insert piping network into the vault box. We have worked through the holes in the box top and/or removed the top of the box. Rope will come in handy for moving, placing, holding, and lowering the unit. It may be advisable to hold step 4B until this time for improved maneuverability. Lower piping network in when glue joints are dry, placing the network in the proper position, with the vertical pipe at the low end of the vault, and the horizontal pipe centered. At this time, vertical pipe may be cut off at a height to match location of motor/blower unit box. Check with Step 7 first.

Step 7

Mount motor/blower unit on concrete pads. Lag bolts can be used to anchor the motor/blower unit to the concrete. This will require drilling of holes through the concrete to place the anchors. It will also be useful to use rubber padding to help in noise reduction. Holes will need to be drilled through the padding before the motor/blower unit is anchored.

A rubber vibration isolator with hose clamps serves as the exit for air from the motor/blower unit. This is a piece of rubber hose which passes through the end of the unit and connects with a piece of cast-iron pipe via an elbow. To minimize potential vandalism, air connections are made of cast iron whenever the pipe is exposed. A 1-in. hole saw will be necessary to penetrate the wall of the building and the latrine box to pass the pipe through. Make appropriate connections to get the piping through. Cut off the PVC vertical section, compensating for an elbow at the top facing the end of the box. Attach a cast-iron section to PVC adaptor, then a cast-iron section to pass through the wall and connect the joints.

Attach the conduit for the electrical wiring and wire in the motor/blower unit according to appropriate procedures. All electrical wiring must be done in accordance with the National Electric Code and local code requirements.

Put a 6-in. fan in the vent stack (if there is one) and wire it in so that it runs constantly. Put the fan near the top of the inside of the building. If there is no vent stack, use a length of 6-in. PVC. Cut through the pipe and roof where appropriate, and insert the fan and wire appropriately. Place a cap on the vent stack, which should extend 1 to 2 ft above the roof line.

APPENDIX E:

LABORATORY RESEARCH OF VAULT AERATION

RSE Engineers conducted laboratory research to evaluate the processes occurring during latrine aeration, specifically volume reduction. A secondary objective was to improve the process' efficiency by optimizing aeration.

Under contract to USA-CERL, lab-scale latrine units were constructed, operated, and monitored in laboratories at the University of Wisconsin, Madison. The first phase of testing used clean water to evaluate evaporation, and the second phase used a synthetic latrine wastewater to study waste treatment. Since hydraulic flow patterns, airflow patterns, oxygen transfer, biodegradation, and evaporation are complex phenomena that cannot be scaled down and duplicated in a lab-scale unit, the study determined the relative effects of key variables. Although the relative effects of the variables studied could not be scaled up and applied directly to actual field units, the data were useful for evaluating latrine aeration and predicting optimum operational strategies. For further information on these experiments, contact the primary author.

Volume Reduction

Studies showed that effects of the variables on volume reduction are significant at the levels evaluated. These variables, in order of magnitude of effect, were:

1. Clean water testing
   a. Humidity
   b. Temperature (water)
   c. Depth
   d. Airflow rate

2. Synthetic waste testing
   a. Temperature (water)
   b. Airflow rate
   c. Air-cycle (those examined were (1) continuous and (2) on 14 hours, off 10 hours)

Assumptions used for this study were that volume reductions in the clean water testing occurred because of evaporation, while reductions in the synthetic wastewaters were the result of a combination of evaporation and biological degradation.

Significant two-factor interactions occurred in both phases of the volume reduction experiments. In the clean water testing, an airflow-temperature and airflow-humidity interaction occurred because of the very small effect of airflow at the low-temperature and high-humidity levels. This was due to the low-moisture-carrying capacity of the cool air leaving the low-temperature columns and the high moisture level of the air entering the high-humidity columns. In the synthetic wastewater testing, significant airflow-temperature and air-cycle-temperature interactions occurred because airflow and air-cycle affected volume reduction much more at high temperatures than at low ones. This agreed with the clean water testing results.

In the clean water testing for evaporative losses, the highest and lowest volume reductions obtained in the laboratory were not measured under temperature and humidity conditions likely to be encountered in the field. Under field conditions, volume reductions

expected from the lab-scale aerated latrines would fall between the two extremes. Volume reductions may be in the 0.50 to 1.00 percent latrine capacity-per-week range. Since the unaerated control columns ranged in volume reduction from 0.1 to 0.6 percent latrine capacity per week, the values predicted for aerated latrines do not show appreciably greater volume reductions due to aeration. Therefore, it can be concluded that at least for the lab-scale latrines, minimal additional volume reduction occurs due to evaporation by latrine aeration.

Volume reductions achieved during the early phase of synthetic wastewater testing were larger than those achieved in the clean water testing. It was assumed that biological destruction of organic matter to CO_2 was responsible, but it was difficult to quantify the additional reductions. It was crudely estimated that an additional 0.5 percent latrine capacity per week was gained at the high temperature level in the lab-scale latrines.

Larger bio-associated reductions may have occurred in the synthetic wastewater testing after longer acclimatization times or with improved dissolved oxygen conditions. Even so, results of this study indicate that overall volume reductions from latrine aeration at conditions representative of field situations are rather small.

Waste Treatment

Pollutant removals varied widely in the lab-scale latrines that treated synthetic human waste. BOD_5 and TOC removals ranged from 6 to 90 percent and 8 to 58 percent, respectively. Specifically, BOD removal was 75 to 90 percent for continuous high rate airflow and 5 to 35 percent for cycled (14 hours on, 10 hours off) high rate airflow. These parameters best illustrated the waste treatment, since major reductions in other parameters, such as solids and total phosphorus, would not be expected due to the nature of latrine operations.

Nitrogen removals resulting from volatilization of ammonia could not be quantified; however, it appeared that significant ammonia removal may have been achieved in the continuously aerated columns at the high temperature level.

Factorial analysis indicated that of the variables evaluated, air-cycle and airflow rate significantly affected BOD_5 removal in the lab-scale latrines for the conditions evaluated. The value of the air-cycle effect was the largest in magnitude, but could not be interpreted separately because of an interaction with temperature. Aeration airflow increased BOD_5 removal by about 10 percent irrespective of the tested levels of the other variables.

A significant temperature/air-cycle interaction occurred because BOD_5 reductions increased with increasing temperature in the continuously aerated columns, but decreased with increasing temperature in the cycled aeration columns. The reason for this was not clear; however, an explanation is available. Overall, it can be concluded that BOD_5 reductions were much higher in the continuously aerated columns than in the cycled aeration columns over all conditions evaluated (Figure E1). This suggests that the aeration cycle evaluated (14 hours on, 10 hours off) may not be suitable for use where waste treatment is desired.

General USA-CERL recommendations are to maintain constant operation of the aerated vault unit and to not use cycling. While these results indicate that volume reductions associated with latrine aeration are small, it appears that simple aeration of

the waste materials in the vault will significantly reduce organic strength and control septic odors. Volatilization of ammonia may also provide significant nitrogen removals, and this aspect of latrine aeration warrants investigation. Although the aeration cycle tested in the laboratory showed rather poor results, other cycles should be tested in an effort to optimize operations.

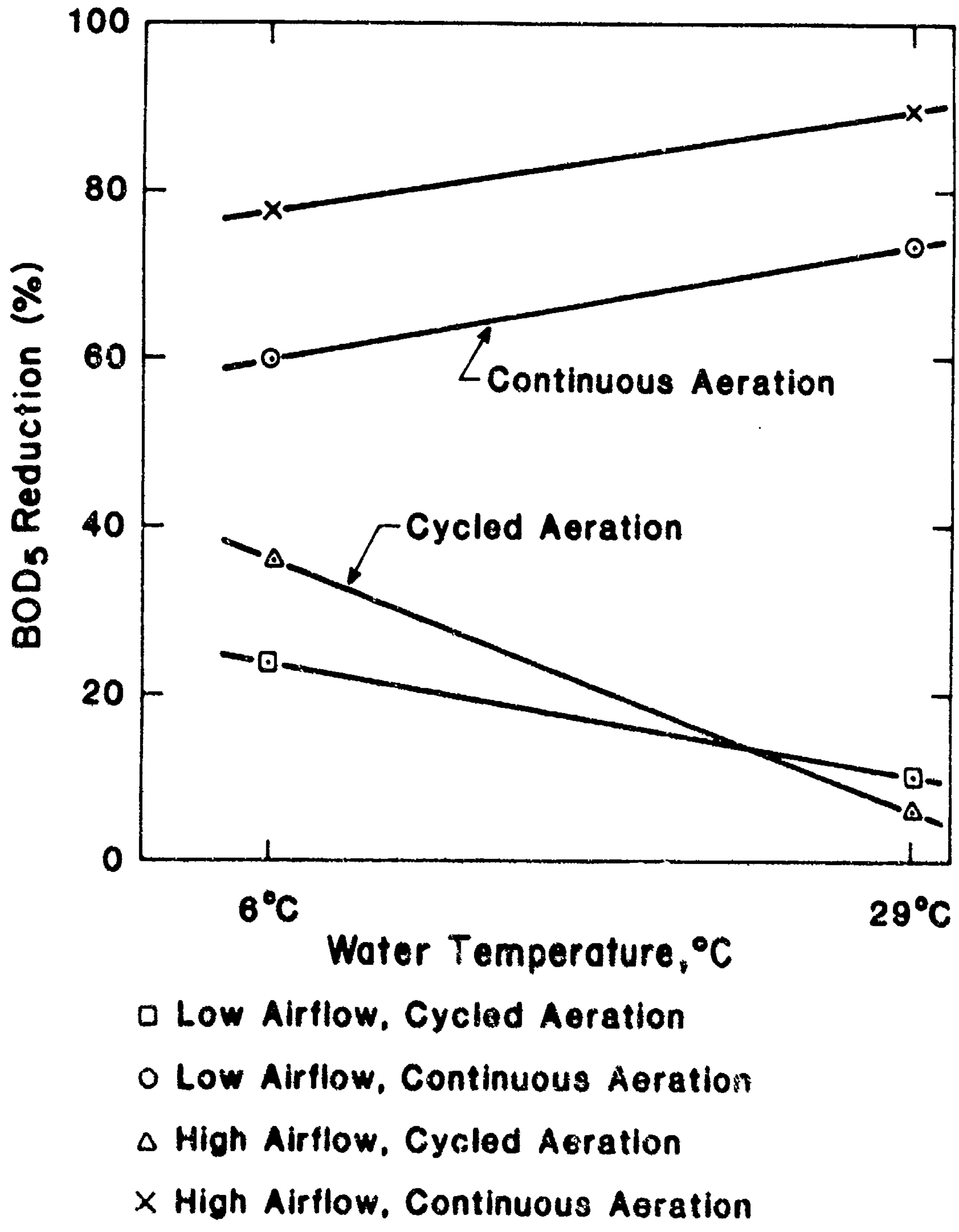

Figure E1. BOD_5 reductions, synthetic waste testing.

APPENDIX F:

LABORATORY RESEARCH ON COMPOSTING LATRINES*

System Design

Large Composting Latrine Unit

The experimental composting latrine used in this study was patterned after a standard Clivus Multrum design. Selection of this design was based on several factors, including:

1. A sloped bottom (30-degree inclination) to facilitate liquid drainage control
2. An interstitial ventilation pattern
3. A successful history of composting latrine applications.

Figure F1 shows the experimental latrine and its relative dimensions. The unit was well-braced and supported and installed indoors within Purdue's Pilot Plant Laboratory (average temperature = 70°F).

The experimental unit was somewhat smaller than a single-family Clivus model, being about 12 in. shorter as well as narrower. The total volume of the unit's composting zone was 35 cu ft; hence, it had about 30 percent of the volume of the Clivus Multrum PF-103 model. The 18,000 annual uses recommended for the Clivus system equated to 5400 annual uses for the experimental latrine, or 15 uses per day.

The experimental unit and the Clivus also differed with respect to their airflow patterns. In the Clivus model, air enters the unit at its lower end, travels through the air ducts, moves upwards through the rear baffle and into the vault's head space, and exits through a vent pipe at the front of the top deck surface (see Figures 6, 14, and 15).

The Clivus pattern had distinct disadvantages. First, and perhaps most important, short-circuiting of the airflow pattern could occur within the vault's head space between an open toilet seat and the vent pipe. Thus, if a toilet seat is left open for extended periods, the aerobicity of the compost pile would likely suffer. Second, a closed toilet seat would lead to short-circuiting unless careful measures were taken to seal out incoming air.

Hence, the airflow pattern on the experimental latrine was modified (Figure F2). An air intake mounted on the latrine's top platform allowed incoming air to pass through the vault's head space. The air was then drawn through a connecting pipe into the ventilating ducts, passing upward through a rear baffle, and then directly to the discharge fan. Thus, an open toilet seat would have no bearing on short-circuiting since the air was vented directly from the rear baffle. Furthermore, this scheme is thought to prevent any possibility of an undesirable gas buildup (e.g., methane) within the head space of the latrine vault.

*This investigation was conducted by J. A. Alleman, et al., Purdue University, under contract to USA-CERL.

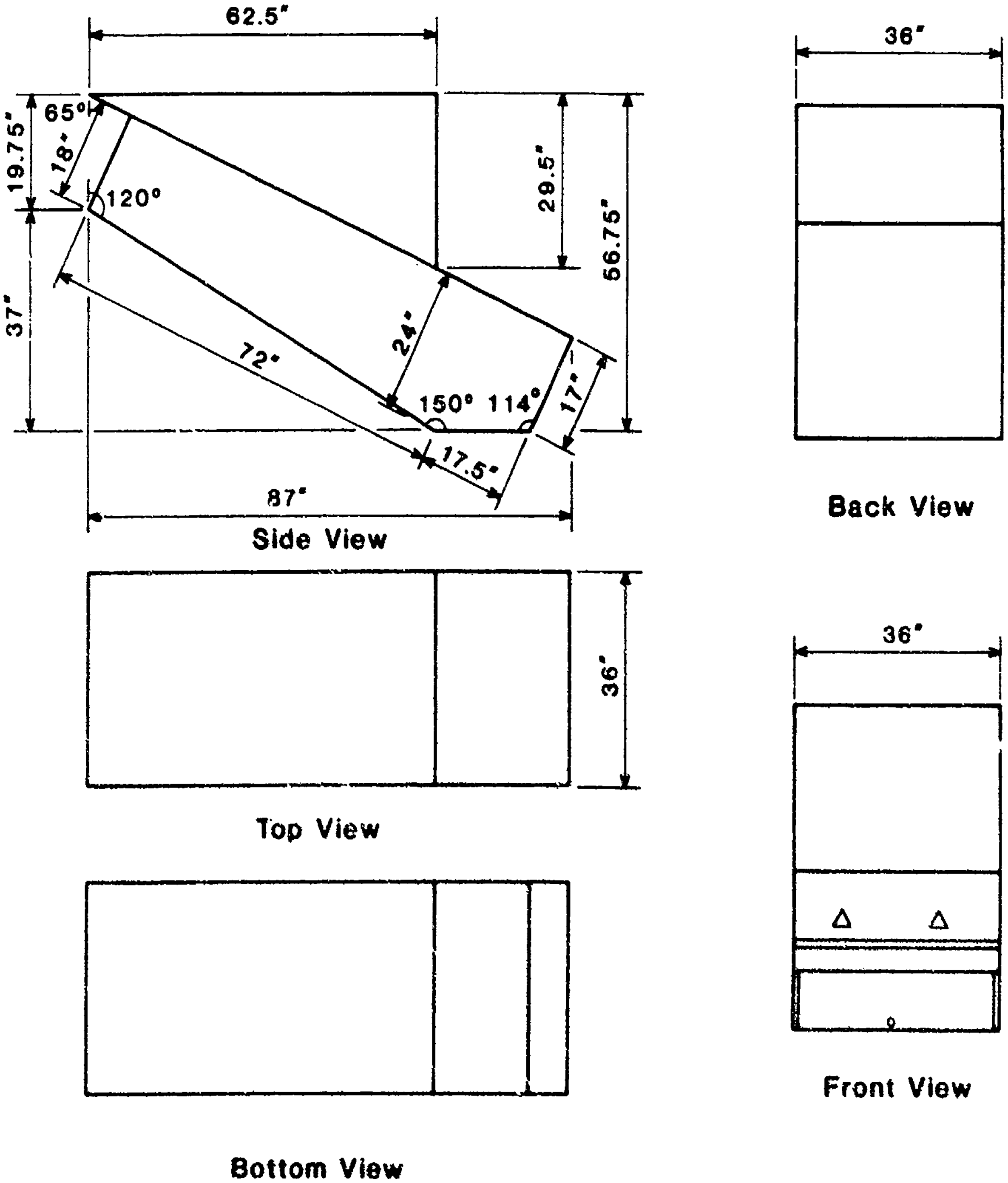

Figure F1. Experimental composting latrine schematic.

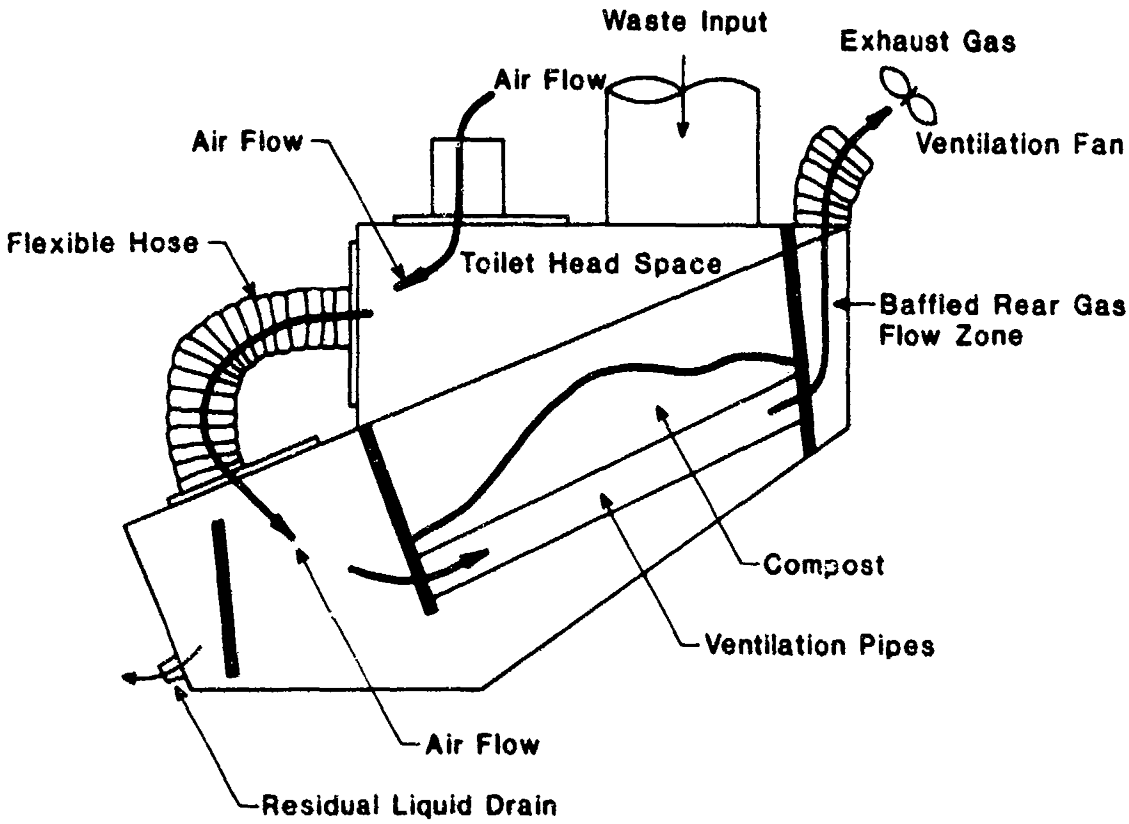

Figure F2. Experimental composting latrine ventilation pattern.

A 115-V AC fan was selected for use in this system, with a peak capacity rating of 115 cfm^{-1}. This fan size basically equates to the fan specification given for the Clivus system. This system's air intake was also designed to accept a restricting orifice plate with variable-diameter openings that regulated actual airflow through the unit.

The airflow rate per unit volume of compost material was expected to be higher than that of an operational Clivus Multrum unit. This increase was considered necessary to negate the undesired occurrence of 250 mL per use residual liquid volumes cited by the vendor.

Small Composting Latrine Units

The small composting systems were not intended to act as true composting latrines, but rather to simulate the environment of the larger system during short-term analytical studies. Each unit was fitted with a ventilation pipe array comparable to that of the larger latrine, including two separate 2-in. diameter PVC pipes that had been drilled with 3/8-in.-diameter holes across their lower quadrants. Figure F3 gives the design features of these small units.

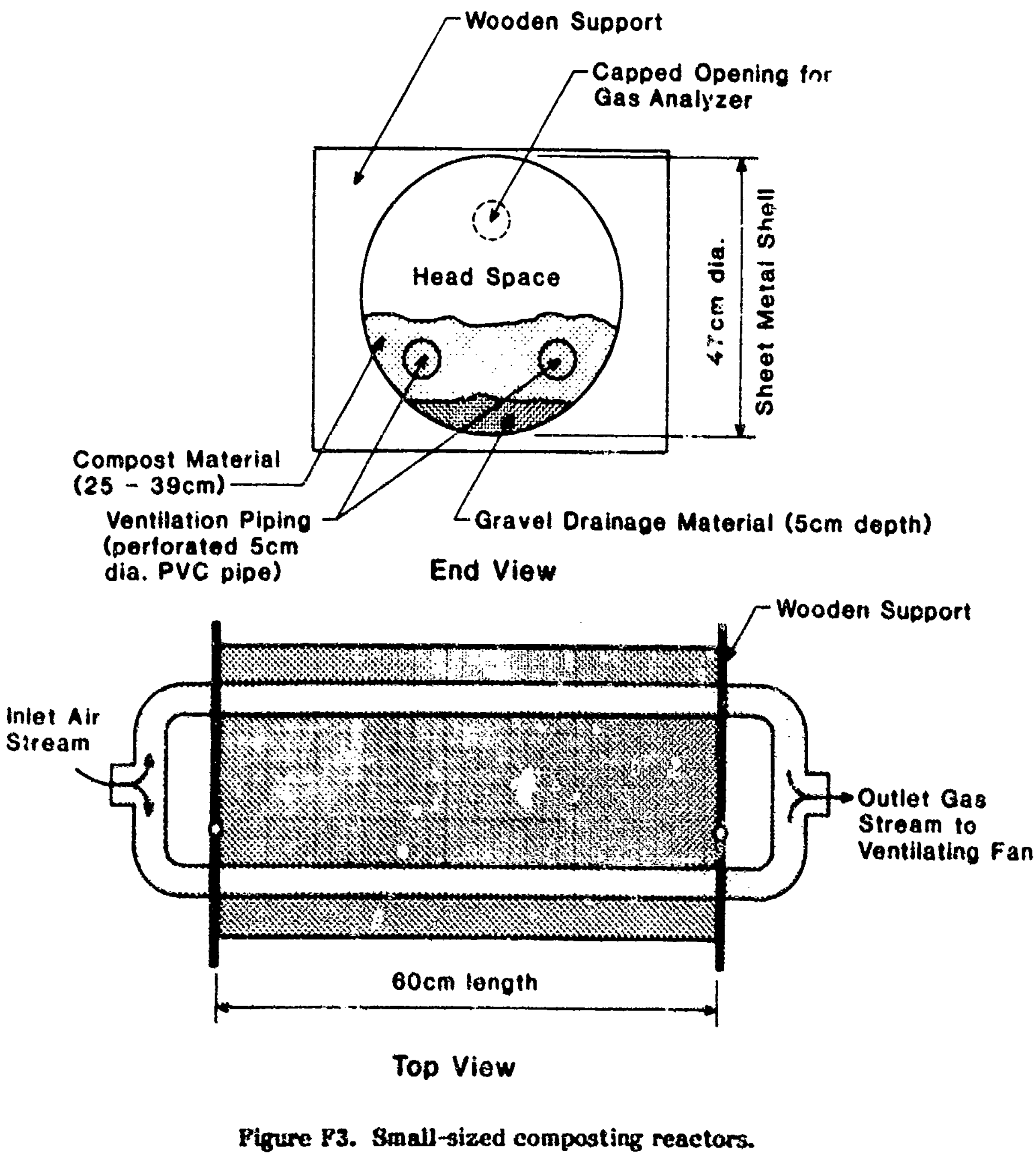

Figure F3. Small-sized composting reactors.

Unit Construction and Startup

Large Composting Latrine Units

Startup of this system was completed in several stages. First, the floor of the unit was covered with a 1-in.-thick fiberglass mat. The mat was intended to convey free liquid directly to the lower front of the latrine. Next, the mat was covered and compressed with a 2-in.-thick layer of gravel. Finally, composted horse manure was placed on top of the underdrain gravel; a fiberglass mat about 8 to 10 in. thick acted as a starter material for the composting pile. Immediately after adding the "starter" material, the pile was thoroughly moistened to an approximate water content of 50 percent and placed in service.

Small Composting Latrine Units

Six identical small composting latrines were built with 3/4-in. plywood ends and 18.5-in.-diameter by 24-in.-long sheet metal bodies. All joints were caulked with silicone sealant. A 7-in.-square opening was also cut into the top of the sheet metal body to provide access to the unit's contents. This opening was routinely covered and sealed with a PVC sheet.

Each small unit was initially lined with a 2-in. gravel base for drainage. The base of each latrine body was also fitted with a drain and plug for draining excess liquid from the system.

Compost taken from the large latrine was then placed in each of the smaller units to a thickness of 10 to 12 in., with a total composting solids volume of about 1 cu ft.

The ventilation tubes of the small units were connected to a central fan housing with flexible plastic tubing; vent gases were then discharged through an adjacent window.

Routine System Operation

Large Composting Latrine

Users of the experimental system voluntarily recorded information about their waste, using "L" (liquid) and "S" (solid) abbreviations. The data were compiled weekly and follow the system's progressive use. A sign was posted in the bathroom to discourage leaving the seat open, mainly to keep undesirable insects out of the latrine area.

Ventilation of the large latrine was kept at the maximum possible rate unless a special test required a change in or discontinuation of the gas flow.

Each week, about 800 mL of bulking material were added to the surface of the pile, including 400 mL of sawdust-wood chips and 400 mL of peat moss. The top 10 in. of the pile surface were then agitated manually with a small tined rake.

All samples needed to evaluate the composting solids were collected. A diary was also kept, with information recorded on evaluations of pile color, insect presence, odors, residual water presence, and pile quantity.

Small Composting Latrine

These smaller units were used for short-term studies and, as such, did not require routine maintenance. Their composting materials were occasionally supplemented with fresh waste from the larger unit; the moisture content of the smaller piles was held near 50 percent, with water added as needed. Ventilation was continuous on the small systems unless a test run on carbon dioxide emission was in progress.

Analytical Procedures

Table F1 identifies all analyses used throughout this project. Carbon dioxide was measured with a Miran-IA portable gas analyzer manufactured by the Foxboro Analytical Company. Tests of CO_2 emissions from both the large and small latrine systems typically involved the following procedure:

1. The ambient external CO_2 level was recorded just before each reactor CO_2 analysis.

2. With the latrine's ventilation system still operative, the head space CO_2 level was determined.

3. Ventilation was subsequently discontinued for a set time period--usually 15 min.

4. The head-space CO_2 level was determined again.

5. Ventilation was resumed until the next cycle of CO_2 analysis.

The data collected were plotted according to the increase in CO_2 within the reactor head space relative to either the ambient (external) CO_2 level or the initial head-space value noted just before ventilation was stopped. The difference between these two data sets (e.g., head space CO_2 at 15 minutes minus ambient CO_2 versus head space CO_2 at 15 minutes minus head space CO_2 at time = 0) was considered to be indicative of CO_2 generated by biological activity when ventilation was discontinued.

Table F1

Analytical Methodologies

Parameter	Method	Reference
pH	pH Probe	Standard Methods, 1985
Temperature	Elect. Thermocouple	
Organic and NH_3-Nitrogen	Kjeldahl Distill.	Standard Methods, 1985
Total Solids	Gravimetric	Standard Methods, 1985
Volatile Solids	Gravimetric	Standard Methods, 1985
Moisure Content	Gravimetric	Standard Methods, 1985
Total Bacteria	TSA Spread Plate	Standard Methods, 1985
Coliform Bacteria	Lauryl Tryptose Broth MPN	Standard Methods, 1985
Fecal Coliform	EC Medium MPN	Standard Methods, 1985
Carbon Dioxide	Infra-Red Spect.	Foxboro/Miran Manual, 1980
Gas Flow Velocity	Hot Wire Anemometer	

Research Results and Discussion

Large Latrine Operation and Loadings

The large latrine system began operations in June 1984 and was kept in continuous service for 12 months. Based on an annual loading rate, this latrine handled about 4380 users. This is about 20 percent below the permissible value of 5400 derived for a volumetric loading equivalent to that of the Clivus Multrum unit. Solids buildup over the test period was relatively nominal. However, this may result from the removal of fresh compost from the large unit for addition to the smaller latrines.

The large latrine showed only one instance of operational stress. This occured when the pile had been severely drenched with water in conjunction with a special performance test, and a residual liquid had to be drained from the lower end of the latrine for 1 week. Otherwise, residual liquid at the base of the latrine was barely adequate for bacterial testing.

Gas flow measurements through the unit revealed a sizeable drop in actual flow compared with the fan's rating (115 cu ft min^{-1}). Velocity measurements taken across the intake pipe opening corresponded to a 34 cu ft min^{-1} airflow and were indicative of head losses that occurred when the gas passed through the piping and composting material.

Exit gas from the latrine had a musty, earthy odor that was occasionally tinged with the smell of urine. However, when the ventilation system was shut down for special testing, this odor did not appear to spread beyond the immediate vicinity of the pile.

The users had no complaints about odors, insects, or any other aesthetic factors. However, the composted horse manure originally placed in the latrine as starter material apparently contained larvae of a small gnat or fly which eventually became endemic to the system. However, these insects remained near the pile and were never observed near the seat or upstairs bathroom. To a certain extent, their population was controlled by pest strips that were occasionally hung within the vault whenever numbers of insects appeared to increase.

Overall, the performance of the large composting latrine was considered satisfactory on the basis of its qualitative behavior.

Large Latrine Performance

Solids-Moisture Levels. Total solids, volatile solids, and moisture percentages were observed within the experimental latrine. The following "pile" locations were used:

1. On top of the pile, directly below the inlet chute

2. Near the bottom of the pile, directly below the inlet chute

3. Near the middle of the pile, "away" (i.e., down) from the inlet chute.

Composite profiles were also generated of these three locations.

The total solids samples taken close to the inlet chute had the lowest values. This location also had the highest moisture content. Total solids levels in this zone typically ranged from 35 to 45 percent. For the lower-strata solids beneath the chute, their total

solids content tended to range between 45 and 60 percent. Samples taken from areas away from the chute generally had higher total solids values, ranging between 45 and 85 percent.

Volatile solids levels below the chute, at both the top and bottom, generally had similar values, ranging between 45 and 55 percent. The magnitude of these values reflected the presence of inorganic chemicals within the waste solids, such as the salt constituents contained in urine.

These volatile solids levels tended to increase slightly over the course of the study. The volatile composition of samples taken from areas away from the inlet decreased consistently. This decrease was considered to be indicative of solids degradation by microbial activity.

Moisture data indicated an increasing trend during the study. The "away" samples had the largest change, ranging from 15 to 20 percent at the beginning of the study to 50 to 55 percent at the end.

Overall, the solids-moisture data indicated several operational characteristics. First, the substrata and "away" (older) solids tended to be drier, apparently correlating with moisture removal from ventilation. Second, the 10 to 15 percent decrease in volatile solids content between "near-chute" and "away" samples likely reflected biological metabolism of the waste material. Finally, the trend toward decreasing solids content and increasing moisture level suggested that the system had not yet reached a stable, steady-state status during the approximate 1-year period of the study. This appears to be consistent with information provided in the literature regarding the time considered necessary for system stabilization.

Bacterial Levels. Total bacteria population started above 1 billion/g and decreased throughout the study. After 230 days of operation, this value had reached 193 million/g.

The trend for total coliform population was similar to that of total bacterial count. Here, the high and low populations were 360 million/g and 1840/g, respectively.

The fecal coliform profile (10 to 50/g) indicates that the fecal coliform fraction of the total coliform or bacterial populations was rather nominal.

The total bacteria, total coliform bacteria, and fecal bacteria populations within residual liquid taken from the experimental latrine's lower drainage zone declined substantially over the period of study. Observed counts ranged between 65 million/mL and nearly zero toward the end of the study. Total coliform population typically fell below 100/mL.

The fecal coliform counts were again quite low, ranging between zero and 40/mL, with a typical norm of 5 to 10/mL. Previous analyses of fecal coliform in the residual liquid of an operating composting latrine indicated similar values (i.e., about 5/mL).

These data collectively indicated that the experimental latrine's solids contained a sizeable bacterial population and that this population tended to decrease during the course of the study. Measurements of nominal population densities of fecal coliforms in both the solid and liquid phases suggested that the latrine environment was not conducive to their survival.

Temperature. Temperature readings were taken at four locations on the composting latrine system, including: (1) within the Pilot Plant Laboratory (i.e., ambient atmosphere), (2) within the head space of the latrine, (3) within the pile, directly below the chute, and (4) within the pile, "away" (i.e., down) from the chute. The ambient and head space readings ranged between 63 and 90°F (17 to 32°C), with a norm of 75 to 80°F (24 to 27°C). However, the pile values had a somewhat lower range of 42 to 90°F (4 to 32°C). However, pile temperatures below the chute tended to be higher than those "away" from the chute by about 2 to 4°C.

Overall, these results did not indicate a significant temperature increase within the pile relative to ongoing metabolic activity. In fact, the pile temperature generally appeared somewhat lower than the incoming gas stream. This decrease was considered to be indicative of evaporative cooling associated with moisture dissipation into the exhaust gas.

Nitrogen Levels. Organic- and ammonium-nitrogen concentrations were measured toward the end of the study. Samples taken from the surface and subsurface pile locations near the inlet chute had total nitrogen fractions of 1.66 and 2.22 percent. The older compost samples, taken at locations away from the chute, had total Kjeldahl nitrogen percentages of 0.97 and 1.42 percent.

This decrease in total nitrogen relative to solids retention was believed to be related to ammonia volatilizing into the ventilating gas stream. The lower nitrogen percentage on the pile surface (e.g., 1.66 percent near the chute and 0.97 away from the chute) can be attributed to the chemical composition of the bulking materials used. The compost solids "age" as they move away from the chute area, and this allows for natural hydrolysis of organic nitrogen. Subsequent removal of ammonium nitrogen might then have occurred in relation to either free ammonia stripping or microbial oxidation.

Carbon Dioxide Emission Levels. Three separate CO_2 emission tests were completed on the large composting latrine at airflow rates of 0.96, 0.25, and 0.06 m^3 min^{-1} (i.e., 34, 9, and 2 cu ft^3 min^{-1}). The two latter studies involved restricting the system's air intake orifice to attain the reduced flow rates. In each test, the ventilation system was discontinued for the entire duration of the 210-min monitoring period.

For an airflow rate of 0.96 m^3 min^{-1} (34 cu ft min^{-1}):

Figure F4 shows the accumulation of carbon dioxide in the composting latrine as a function of the time after the inlet and outlet vents were closed. When the fan was on the airflow rate was 0.96 m^3 min^{-1} (34 cu ft min^{-1}) and represented flow through an unrestricted 10-cm. (4-in.) diameter opening. The volume of material in the composting latrine during this study was about 23 cu ft.

The data points on Figure F4 represent three combined sets of independent CO_2 readings taken on separate monitoring days. The following power function has been developed to model this data pattern:

$$Y = 33.416\ T^{0.636} \qquad \text{[Eq F1]}$$

where:

T = time the composting latrine was sealed, minutes
Y = change in concentration of carbon dioxide relative to T=0.

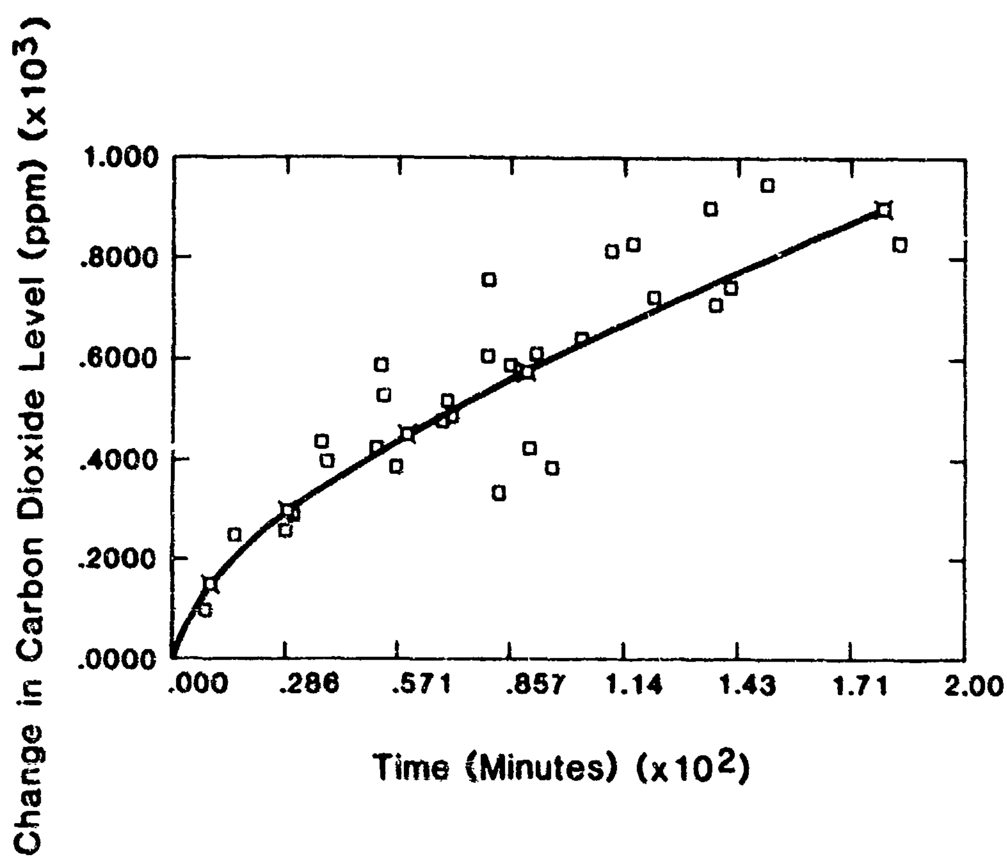

Figure F4. CO_2 buildup; ventilation rate = 0.56 m^3/min.

The coefficient of fit on this model was 0.976. Data values beyond 210 minutes could not be recorded because the carbon dioxide levels generated were beyond the calibrated range of the Miran 1-A instrument (1300 to 1500 ppm).

As the carbon dioxide in the composting latrine increased, oxygen available to the microorganisms decreased. Although not evident in Figure F4, beyond 4 to 5 hours, the CO_2 profile probably would have flattened out as aerobic metabolism dwindled, possibly being replaced by anaerobic activity.

Based on a linearization of the initial data points collected during this study, the maximal rate of CO_2 buildup within this latrine was determined to be 11.1 ppm per minute. In turn, this buildup corresponded to a carbon dioxide release rate of 7.4 mg CO_2 per minute.

For an airflow rate of 0.25 m^3 min^{-1} (9 cu ft min^{-1}):

Figure F5 shows the accumulation of CO_2 in the restricted 0.25 m^3 min^{-1} airflow composting latrine as a function of time after the vents were closed and the fan turned off. Two sets of data are given in this figure, including one set of CO_2 readings taken just 5 days after the transition from 0.9 to 0.25 m^3 min^{-1}, and a second set taken more than 1 week after the transition. The progressively negative effect of the reduced airflow rate on the system's metabolic viability is readily evident when these two data sets are compared.

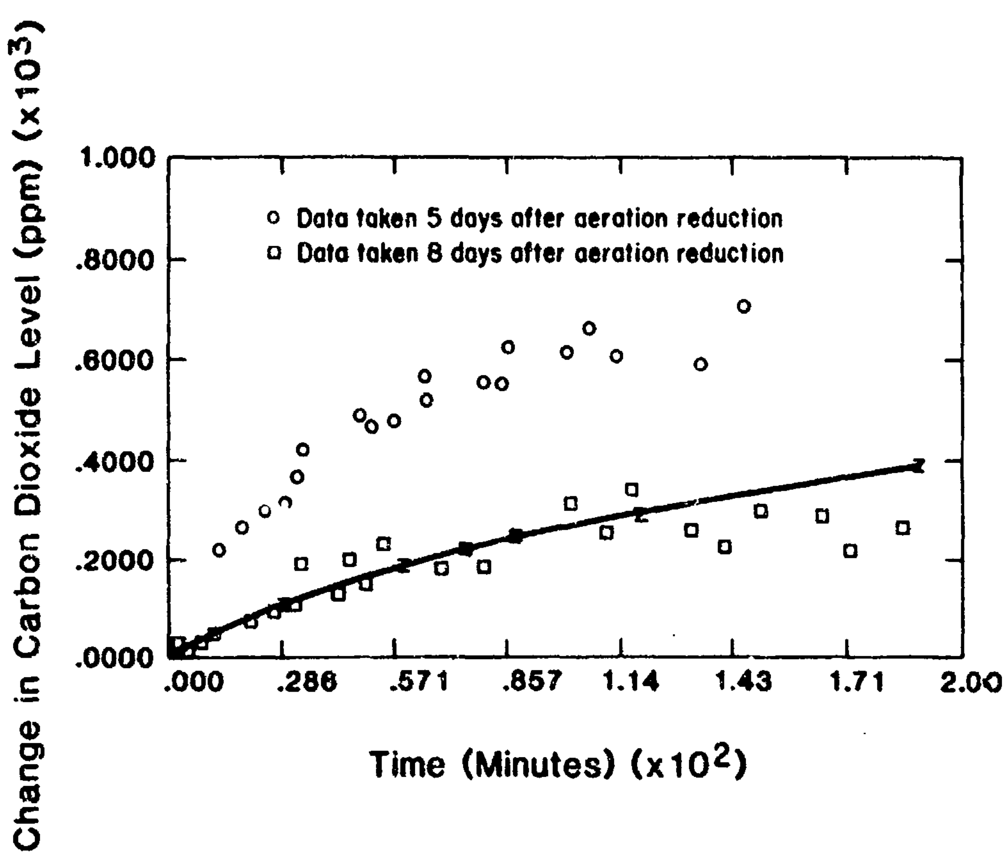

Figure F5. CO_2 buildup; ventilation rate = 0.25 m^3/min.

After 5 days, the CO_2 generation rate was much lower than the rate observed in conjunction with the higher airflow. After 1 week, the CO_2 increase fell below 400 ppm after the 210-min test period.

The following model was developed to fit the latter CO_2 emission profile:

$$Y = 11.46\ T^{0.67} \qquad \text{[Eq F2]}$$

where:

T = time the composting latrine was sealed, minutes
Y = change in concentration of CO_2 relative to T = 0.

The coefficient of fit on this power function model was 0.97.
For an airflow rate of 0.06 m^3 min^{-1} (2 cu ft min^{-1}):

The CO_2 emission profile given in Figure F6 for a latrine acclimated to 0.06 m^3 min^{-1} airflow is rather similar to that of the 0.25 m^3 min^{-1} operation (Figure F5). In this case, the data were fit to the following power function curve with a 0.96 coefficient of fit:

$$Y = 18.37\ T^{0.59} \qquad \text{[Eq F3]}$$

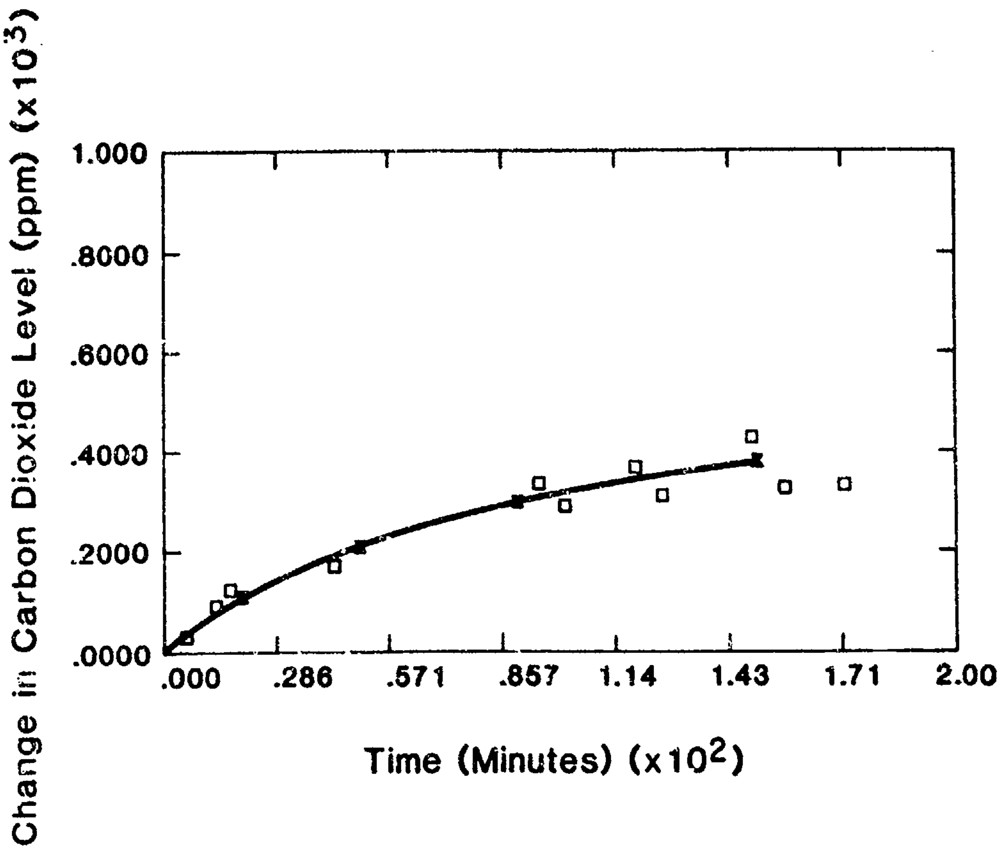

Figure F6. CO_2 buildup; ventilation rate = 0.06 m^3/min.

where:

T = time the composting latrine was sealed, in minutes
Y = change in concentration of CO_2 relative to T = 0.

Overall, tests at flow rates of 0.25 and 0.06 m^3 min^{-1} both demonstrated a decrease in CO_2 release. However, none of these tests showed strong evidence for significant biological activity within the latrine. At best, the highest airflow rate showed a maximal CO_2 release rate of 7.4 mg CO_2 min^{-1}.

Small Latrine Performance

Four separate series of tests were conducted on the set of small units. The first series of tests examined the effect of moisture on CO_2 release from composting soils. The second series evaluated the apparent viability of "aged" compost solids. The third set of tests addressed the relative effect of supplemental substrate additions, including sawdust wood chips, newspaper, and food wastes. The final set of tests focused on short-term system response to several specific organic chemicals in an attempt to develop an expedient technique for assessing the metabolic viability of composting latrines.

Effect of Moisture Addition. This series of experiments was designed to evaluate the effect of simple water addition on the activity of composting materials. Four separate test reactors were used in the study; each one was initially loaded with about 1 cu ft of fresh compost solids from the large latrine, treated with water, if necessary, to obtain a 50 percent moisture content, and then allowed to equilibrate for 2 days with continuous ventilation at a 4 to 6 cu ft min^{-1} airflow.

Following this preparative procedure, each small unit was then dosed with a different volume of water, ranging from 0.5 to 2.0 L. These reactors were then monitored for 72 hours for their CO_2 levels relative to either the background CO_2 concentration in the box immediately preceding each test or to the ambient CO_2 level. The ventilation to each small reactor was resumed between CO_2 measurements.

In comparison to CO_2 studies for the larger latrine, the detector's exhaust gas stream was not recycled back to the units. Hence, these CO_2 changes tend to be smaller than for the larger unit. Figures F7 through F10 show the study results.

Addition of 2.0 L of tapwater produced the highest immediate CO_2 generation levels. However, at this rate of water addition, excess water could be drained through the bottom of the reactor. Over time, CO_2 production decreased steadily.

The pattern for CO_2 generation after addition of 1.5 L of water was quite similar to that described in the preceding paragraph. However, both of the lower additions (Figures F7 and F8--1.0- and 0.5-L additions, respectively) produced much less CO_2. As such, the moisture content of the solids appeared to have a substantial effect on the system's microbial activity.

Effect of Compost Aging. The previously discussed CO_2 emission patterns observed at the two higher levels of water addition (Figures F9 and F10) both tended to decrease over the 72-hour study. This drop was believed to represent a change in the character of the waste material. Therefore, each of the previously used reactors was given an additional water supplement equal to its original water dose and then monitored for subsequent CO_2 emissions. At the time of the second water additions, the compost within each reactor was 160 hours old (i.e., after removal from the large latrine as "fresh" material). However, as shown in Figures F11 through F14, these additions had a negligible effect on CO_2 emissions.

Effect of Varied Substrate Presence. The level of microbial activity, as measured by CO_2 generation, was tested with three different substrates, including newspaper, sawdust, and household food waste. In one other control test, only water was added. This test series evaluated the relative usefulness of these alternative substrate forms for use in a composting latrine.

All of the reactors used in this test had been filled previously with about 1 cu ft of fresh compost from the large latrine, dosed with water to a 50 percent moisture level, and ventilated for 2 days at 4 to 6 cu ft min^{-1} prior to any substrate addition. Newspaper was tested at addition levels of 20 and 40 g per reactor. A supplement of sawdust and wood chips (an approximate 50-50 blend of Douglas fir and white oak species) was added at levels of 80 and 160 g per reactor. Food wastes were tested at 725 g per reactor. Throughout the test period, a moisture content of 50 percent was approximately maintained within the reactors, using water additions as necessary.

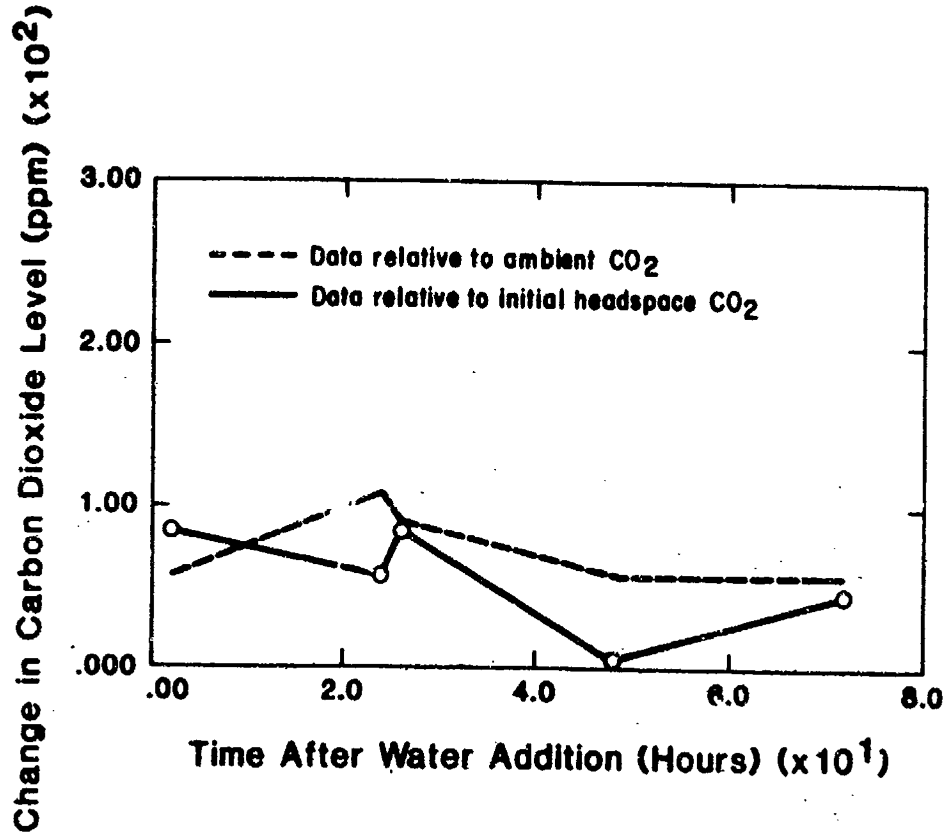

Figure F7. Chronological CO_2 release within small-sized reactor dosed with 0.5 L of water.

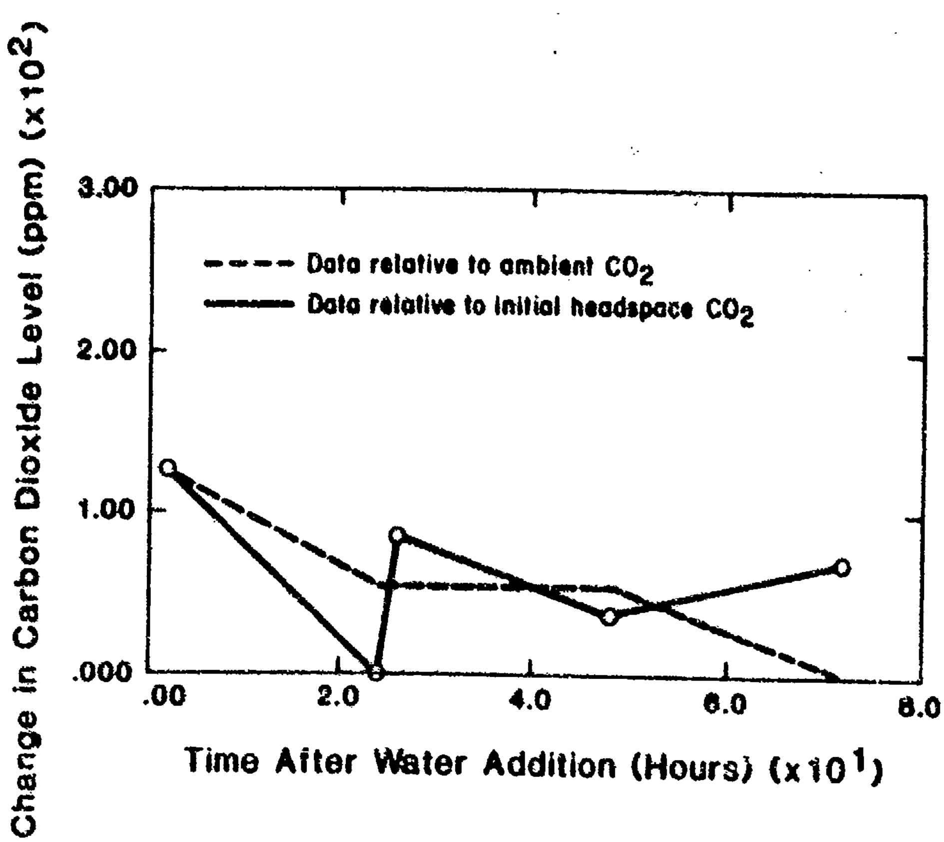

Figure F8. Chronological CO_2 release within small-sized reactor dosed with 1.0 L of water.

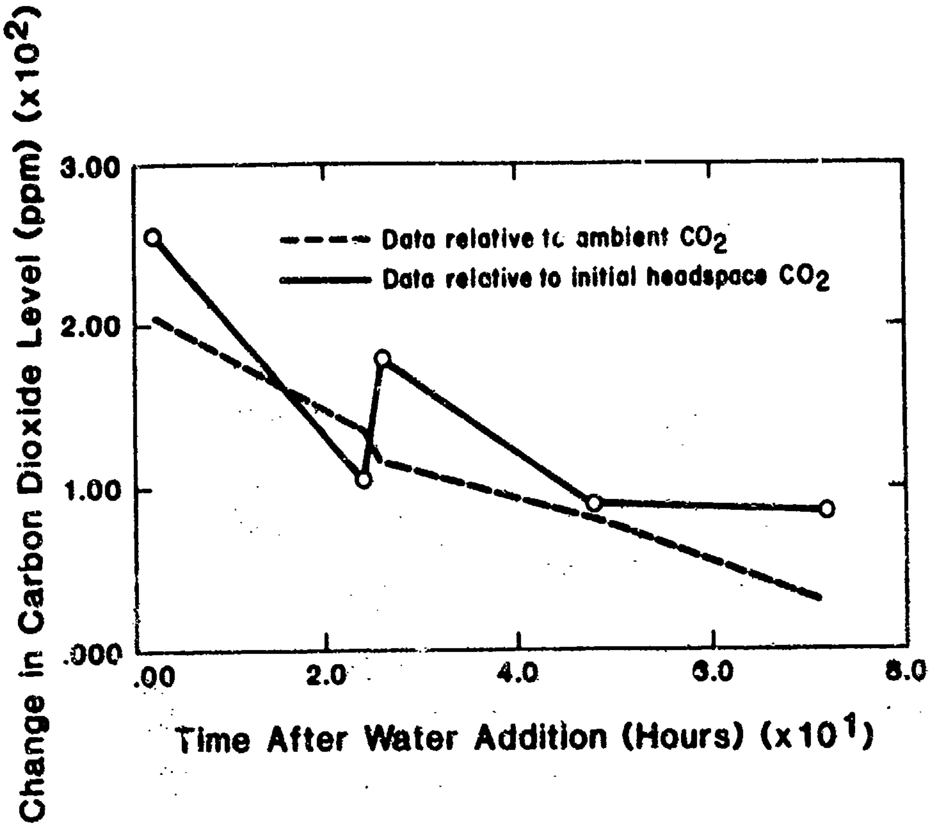

Figure F9. Chronological CO_2 release within small-sized reactor dosed with 1.5 L of water.

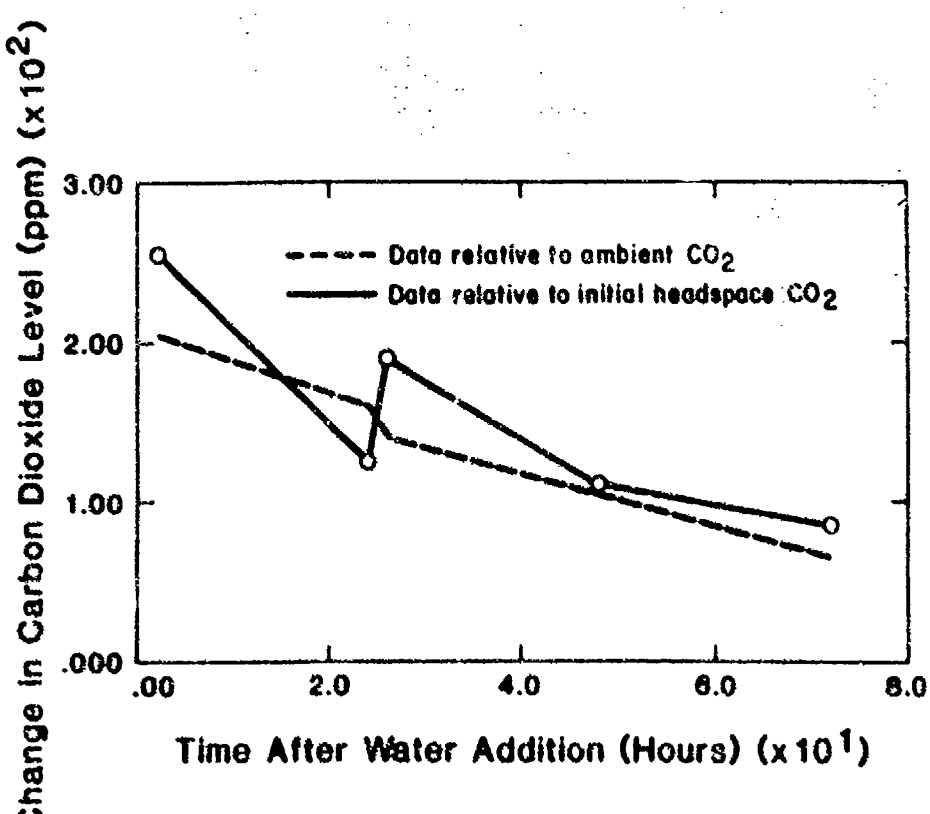

Figure F10. Chronological CO_2 release within small-sized reactor dosed with 2.0 L of water.

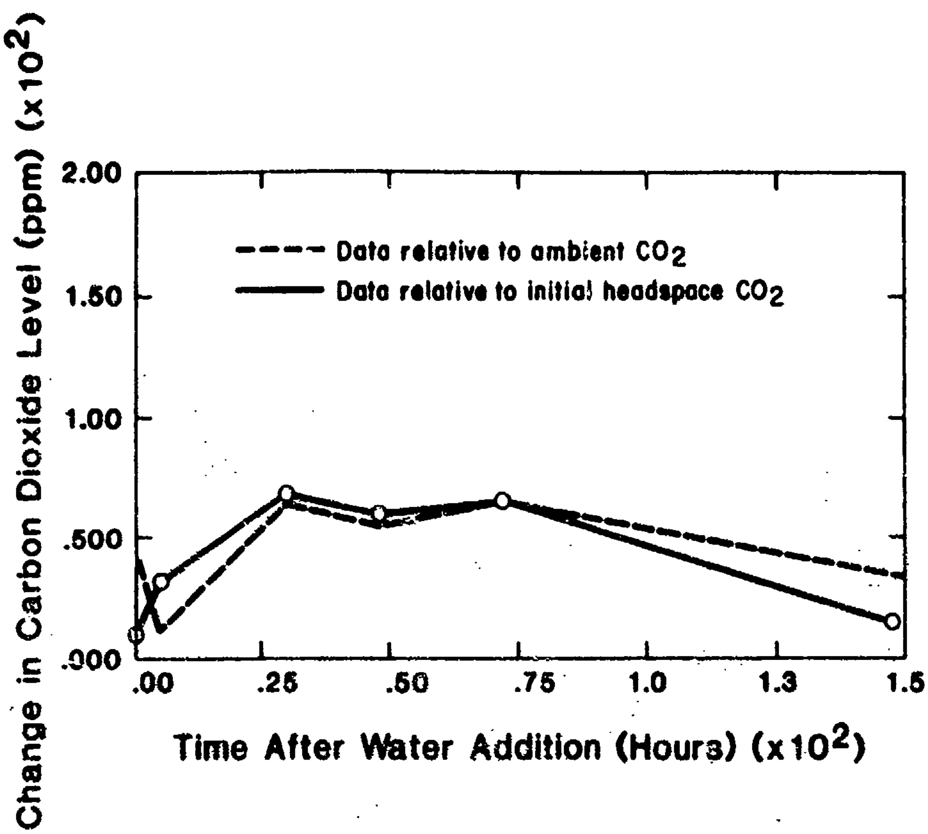

Figure F11. Chronological CO_2 release within "aged" small-sized composting reactor dosed with 0.5 L of water.

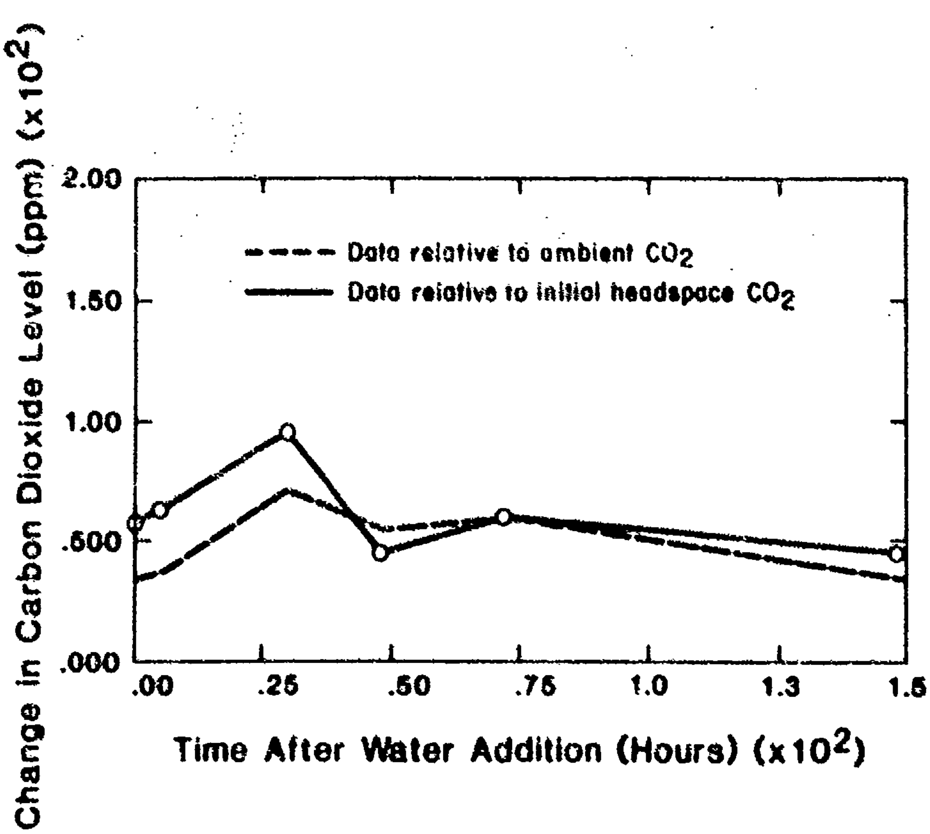

Figure F12. Chronological CO_2 release within "aged" small-sized composting reactor dosed with 1.0 L of water.

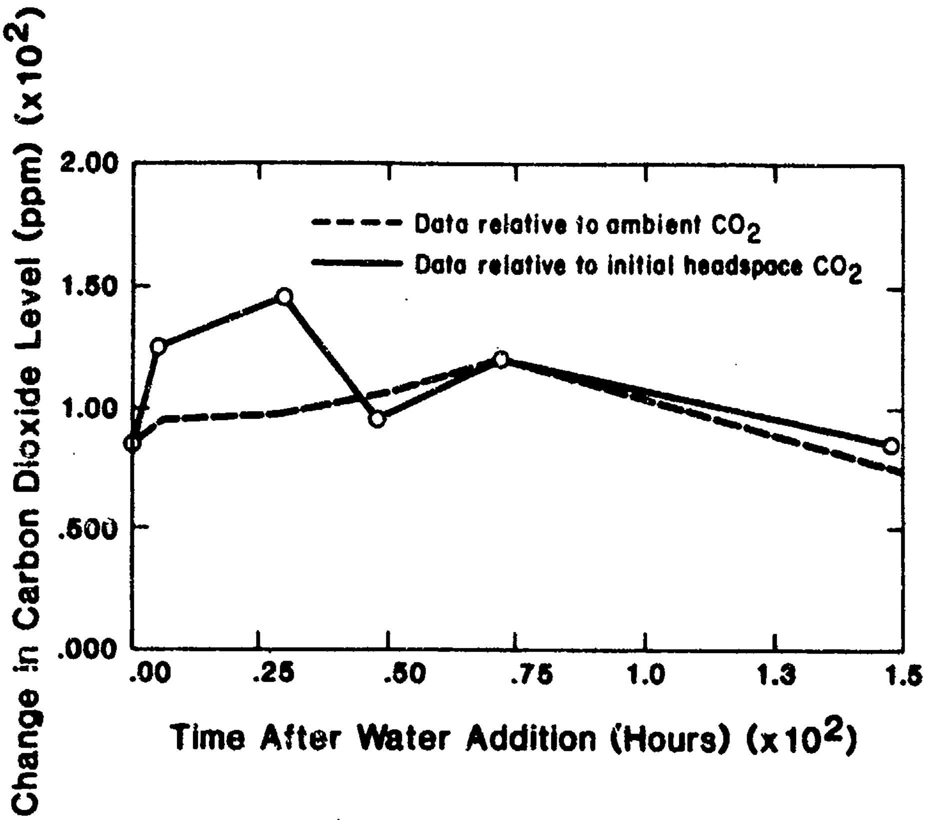

Figure F13. Chronological CO_2 release within "aged" small-sized composting reactor dosed with 1.5 L of water.

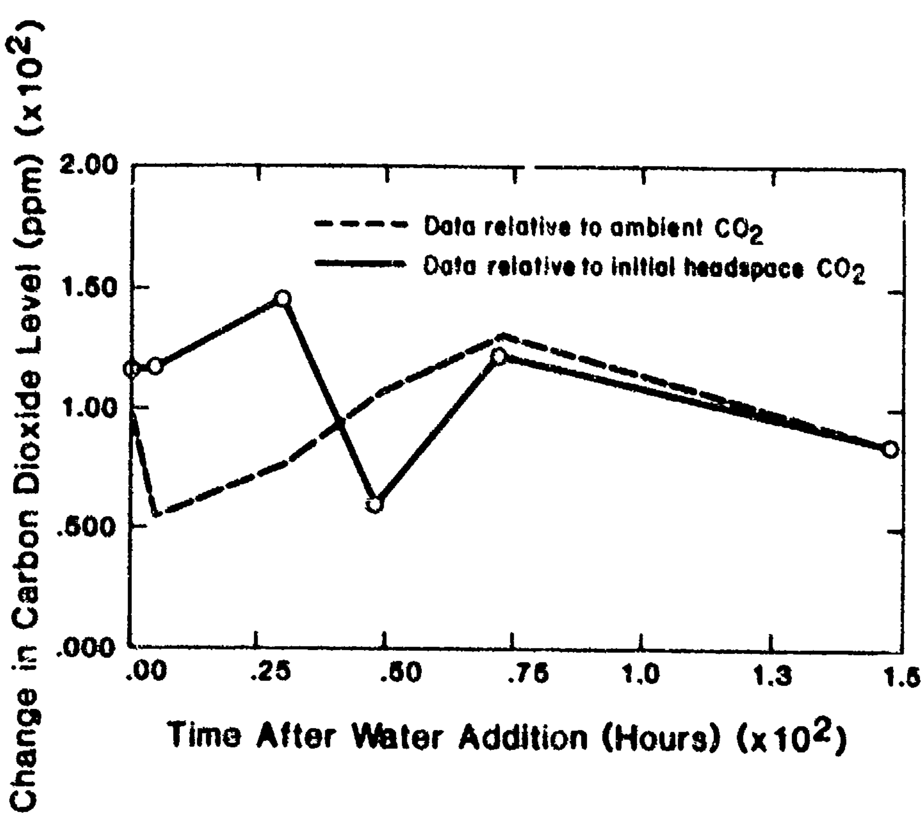

Figure F14. Chronological CO_2 release within "aged" small-sized composting reactor dosed with 2.0 L of water.

Water addition alone affected CO_2 emission. However, this output again faded during the 18-day study period, as noted by the convergence of the two CO_2 profiles (relative to either the ambient CO_2 level or the initial CO_2 value within the reactor's head space) and their proximity to the 0 ppm CO_2 difference datum.

The 80-g sawdust and wood chip addition had only a nominal effect on the CO_2 release. However, the 160-g sawdust/wood chip input greatly affected CO_2 production, with the effect on CO_2 lasting the entire 18 days of observation. At the end of the study period, the CO_2 variation levels still exceeded 300 ppm.

Additions of newpaper at 20 and 40 g both demonstrated a positive impact on CO_2 emission, although not quite to the extent associated with the higher sawdust/wood chip addition. Interestingly, both of these additives had a pronounced effect on water retention within the system. Each reactor treated with these materials routinely required a much higher dose of water to maintain the desired 50 percent moisture level. This was believed to result from the improved permeability and void content of the composting solids produced by these bulking materials.

The food waste addition produced the highest increase in CO_2 in the small-sized reactors. After 18 days, the CO_2 variation still exceeded 600 ppm. Although not plotted, another study of food waste addition was completed in which the food waste had previously been autoclaved to kill its inherent bacterial population. However, this material resulted in nearly the same CO_2 release pattern. Hence, the contribution of food waste to the system's viability did not result from additional bacteria, but rather from its substrate contribution to bacteria already within the reactor. Control over moisture levels within the food-waste-treated system was not nearly as tedious as with the newspaper and sawdust/wood chip strategies.

Viability Assay Determination. This experiment was conducted to find a substance that would rapidly produce CO_2 when put into a composting latrine. Generation of CO_2 would indicate that the latrine was functioning properly and had a healthy population of microorganisms. Five substances were tested at varying concentrations: soluble starch, acetic acid, propionic acid, lactose, and citric acid. All five were initially diluted into 1-L aliquots of tapwater which were then evenly spread over the top surface of the composting solids.

Citric acid and acetic acid were tested to see whether materials associated with the tricarboxylic acid (TCA or "Krebs") cycle would generate high levels of CO_2. The lactose and propionic acid substrates were included because limited anaerobic activity within a composting latrine would generate them.

The starch additions were conducted at 20 and 40 g per reactor. In comparison with an "undosed" reactor, either starch addition had a positive effect on CO_2 emission. The 40-g starch addition had the highest effect, resulting in a peak value of about 400 ppm CO_2 difference.

Acetic acid additions were completed at 20- and 100-mL levels. Both additions had a pronounced effect on CO_2 output, with the 100-mL acetic acid input resulting in a peak CO_2 difference of about 600 ppm.

Citric acid was added at levels of 10, 25, and 50 g. The sizeable impact of citric acid on this test occurred at the 100-mL dosing level with a maximum CO_2 difference of about 800 ppm.

Lactose additions were completed at 10, 25, and 50 g per reactor. The data suggest that the presence of starch may actually have had a detrimental impact on the unit, since progressively lower CO_2 differences were noted as more starch was added.

Summary

The following discussion of this system's design and performance is subdivided according to the factors considered to be the primary technical parameters for a composting latrine:

System Loading

The experimental unit received a volumetric loading of 4380 annual uses per cubic meter of composting vault volume. This is somewhat below the suggested capability of the Clivus Multrum Model PF-103 unit (5800 annual uses per cubic meter), for an operating temperature of about 20°C. However, the general absence of residual liquid in the experimental latrine suggested that its loading could have been increased to a level closer to the suggested value for the Clivus unit.

Evaluation of the loading parameter on the basis of annual uses per unit of composting volume (which then corresponds to a given volumetric waste input) appears to be a reasonable design approach. Therefore, the recommendation for determining system loading would be to use a conservative design value of 5000 annual uses per cubic meter of composting vault volume. This figure may require site-specific adjustment on the basis of typical operating temperature and waste input characteristics. For example, a cold-weather operation or predominantly liquid-type loading pattern would both require lower system loadings.

System Aeration

Guttormsen's[20] analysis of the evaporative demands on a composting latrine indicated that about 10 L of moisture would be removed each day given a ventilation rate of 1.0 $m^3\ min^{-1}$. For the experimental latrine, about 4.2 L of liquid were to be removed each day. However, this system was provided with a ventilation rate of 0.96 $m^3\ min^{-1}$. Thus, it had more than twice the ventilation rate considered necessary by Guttormsen's analysis. However, there was only a nominal temperature increase when gas passed through the pile. Furthermore, the normal absence of a residual liquid suggested that this unit was somewhat underloaded and/or overventilated.

The Clivus Multrum unit has a recommended fan sizing of 3.25 $m^3\ min^{-1}$ (115 cu ft min^{-1}) and an apparent liquid removal requirement of about 17.2 L in conjunction with its average of 49 daily uses. This ventilation rate also represents an approximate doubling of the equivalent Guttormsen level. However, the Clivus ventilation rate represents an apparent maximum fan rating rather than an operational rate, and includes energy losses during gas passage through the pile and plumbing. Hence, the Clivus ventilation rate may actually be closer to Guttormsen's theoretical level. Therefore, the recommendation on system aeration would be to use a conservative design value of 1 $m^3\ min^{-1}$ ventilation throughput for each 5 to 6 L of required liquid removal.

[20] Dag Guttormsen, "Evaluation of Compost Toilets - A Field and Laboratory Update," NSF Sixth National Conference (National Sanitation Foundation, 1979), pp 147-153.

Bulking Material Addition

Clivus Multrum operating literature recommends adding 0.03 to 0.06 m^3 (1 to 2 cu ft) of bulking material per 1000 uses. At this rate, annual addition to the experimental composting latrine (4380 annual user inputs) would have been 123 to 246 L of material. However, the actual addition was only 800 mL per week for a yearly total of 42 L.

The extent of manual raking likely affects the volume of bulking material needed. For example, the experimental unit received much less bulking material than what was recommended, but was raked weekly. Hence, "bulking" of the waste was promoted by mechanical agitation and by addition of this nominal bulking material volume (i.e., at about half the dry volume of the input waste).

On the other hand, the higher bulking material additions placed in a Clivus system, at a volume ranging up to double the actual waste input, may decrease the necessary raking frequency because it improves the pile's gas throughput characteristics. Therefore, the recommendation on bulking material addition would be to use a conservative figure of 0.03 m^3 per 1000 latrine uses, and to rake the top 10 to 12 cm of the pile at least semi-monthly, and preferably more often.

Carbon Dioxide Emission

The CO_2 generation rate measured in conjunction with the composting latrine's highest ventilation rate was to be 7.4 mg CO_2 min^{-1}. This corresponds to a daily CO_2 release of 2.9 g organic carbon, or about 6 g of degradable solids from the experimental unit. However, this mass of apparently oxidized solids represents a nominal fraction of the input waste. The experimental system's daily 12 uses would be expected to amount to 360 g of dry solids (at ≈ 30 grams per use), of which half might be considered degradable (the urine solids fraction of the total solids mass is made up mostly of nondegradable salts). Hence, the 6 g of oxidized solids would be less than 3 percent of the total degradable solids level added each day by the 12 users.

In turn, the CO_2 emission results do not appear to support the premise of significant biological activity within the experimental latrine. Indeed, if the latrine's level of metabolic oxidation were at all comparable to the daily solids input, the exhaust gas stream should have had a measurable CO_2 increase over the ambient inlet gas concentration. However, this change was never observed to be significant. Therefore, the latrine had to be placed in a nonventilated batch mode to assess its release of CO_2.

Temperature Change

In contrast to the general values provided in the literature, the experimental latrine showed only a nominal increase in its interior temperature. However, this behavior is consistent with what has been reported by other long-term Clivus system users.

The experimental unit's ventilation rate may have been a factor leading to this behavior. The cooling rate provided by the gas stream may have exceeded the thermal output produced by biological activity. The fact that the CO_2 testing showed only a nominal measure of biological activity would also coincide with this observation, since this activity represents the source of the released energy.

Overall Mass Balance

Study results suggest that the primary mechanism of the experimental composting latrine was that of its capacity for moisture removal. This evaluation was based on observation of several factors, including:

1. The nominal CO_2 emission rates
2. The nominal decrease in the volatile solids fraction
3. The nominal temperature increase within the composting pile interior
4. The consistent decrease in bacterial population within the composting solids.

However, based solely on the moisture removal mechanism, this latrine could theoretically have been used at a similar loading rate for 2 to 3 years before any residue would need to be withdrawn (i.e., given an annual dry waste and bulking material input of about 0.15 m^3).

By comparison, the "dry" residue buildup within a fully loaded Clivus system (18,000 annual uses) would be about 1.0 m^3, given its higher rate of bulking material addition. However, the fact that Clivus Multrum operational literature indicates a typical annual compost withdrawal volume of 0.2 m^3 (7.5 cu ft) for the PF-103 system suggests that a great deal of biological activity would be necessary to account for this continued reduction in the waste volume.

The major insights provided by the small reactor studies centered around the usefulness of various bulking materials and on the possibility of diagnostically evaluating a composting latrine's metabolic activity using a short-term CO_2 assay.

Although additions of sawdust/wood chip and newspaper were both apparently beneficial, the use of food wastes had the most pronounced impact on CO_2 release. This likely reflects the lower C:N ratio of the food waste, such that the bacteria could more readily metabolize it. However, each of the cellulitic substrates was found to have a sizeable effect on dewatering of the composting solids. Systems prone to excessive liquid buildup or those that typically receive a higher urine input relative to their overall loading would undoubtedly benefit from the use of either of these materials.

Of the potential "diagnostic" chemicals, citric acid produced the largest increase in CO_2 release. Although this approach must be verified, it appears that it may be possible to add a citric acid solution to an isolated composting latrine (i.e., with its ventilation system turned off) as an expedient means of determining its relative metabolic activity.

APPENDIX G:

O&M SURVEY QUESTIONNAIRE

DATE____

Facility Name ______________
Type of Facility ____________

Location _________________ Number of Tanks ____/____

POC ______________ ______
Approx. Cost per Tank _________

Phone ___________________
When Installed ____________

Amount of Use (weekly avg. per tank)

Light (0-10/day) ___ Med. (10-50/day)___ Heavy (50-100/day) ___

Spring ___ Summer ___ Fall ___ Winter ___

Weekdays ___ Weekends ___
Counter Yes __ No _

Operation and Maintenance Practices

Bulking Agent

Type ___ How much ___ How often ___ By whom _____

Pile Mixing

Yes ___ No ___ How often ___ By whom ___

Removing Compost

How often ___ How much ___ Where put ___ By whom ___

Liquid Removal

Leach Line __ Pump __ How often __ How much ___

Fan Operation

Continuous __ Intermittent __ When ___ AC ___ Solar ___

Toilet Seats

Auto Closers __ Manual Close ___

Inspection

Condition of Pile __ Fan (airflow) __ Odors __ Liquid Accum. __

Seats __ How often ___ By whom _______

Records Kept

Yes __ No __ On what _________________

User Acceptance

Cleanliness: Cleaner than other units __ Less clean __ Same __

Vandalism: Less than other units __ More __ Same __

Toilet Seats: Usually closed __ Left open __

Problems

Odors ___ Liquid accumulation ___ Pile too high ___ Insects ___

Bulking agent supply ___ Regular addition of agent ___

Other problems ____

Operation and Maintenance Costs

Lower than other systems ___ Same ___ Higher ___

If higher, is it justified? Yes ___ No ___

Comments

Satisfied with units Yes ___ No ___

Do you think it's composting or just storing/dehydrating?

Composting___ Not composting ___ Uncertain ___

Installed Cost Low ___ Reasonable ___ Too high ___

Would you buy more units? Yes __ No ___

General Comments ____

____

____

____

APPENDIX H:

O&M SURVEY SCORING METHOD

Use:

1 - Very light	(0-10/day)	Short season, day use
2 - Light	(0-10/day)	Spring thru fall, day use
3 - Med.	(10-50/day)	Spring thru fall, day & night use
4 - Heavy	(50-100/day)	Spring thru fall, day & night use
5 - Very Heavy	(100+/day)	Year-round, day & night use

Operation and Maintenance:

		Score	Total Possible
Bulking Agent:	None added	0	
	Added occasionally	1	
	Added regularly	2	0 5
	Peat moss, paper	1	
	Leaves, grass, food stuffs	2	
	Sawdust, chopped straw	3	
Maintenance Labor:			
	None	0	
Pile Mixing:	Occasionally	1	
	Regularly	2	
Compost Removal:	Not at all	0	
	Once or twice	1	0 6
Liquid Removal:	Not at all	0	
	Pump occasionally	1	
	Pump regularly	2	
	Leach line	3	
Ventilation:			
	Wind turbine	0	
Seats Open	Daylight fan	1	
	Continuous fan	2	0 5
	Wind turbine	3	
Seats Closed	Daylight fan	4	
	Continuous fan	5	
Inspection:	Once or twice/year	0	
	Occasional odor check	1	
	Visual check every 6 mo.	2	0 4
	Monthly visual check	3	
	Thorough weekly check	4	
	Total O&M Score Possible:		0 20

Performance:

		Score	Total Possible	
User Acceptance:	Like unit	+1		
	Neutral	0	-1	+1
	Don't like unit	-1		
Operational Problems:	No problems	4		
	-1 for each minor problem		-4	+4
	-2 for each major problem			
O&M Costs:	Lower than other systems	+1		
	Same or no comparison made	0	-1	+1
	Higher than other systems	-1		
Owner Comments:	Satisfied with unit	+1		
	Dissatisfied	-1		
	Composting	+1		
	Uncertain	0		
	Not composting	-1	-4	+4
	Reasonable first cost	+1		
	Not known	0		
	Too expensive	-1		
	Would recommend buying more	+1		
	Wouldn't recommend	-1		
Total Performance Score Possible			-10	+10

Table H1

O&M Survey Results

Facility Number	Number of Tanks	Age (yrs)	Use	Bulking Agent	Maintenance Labor	Ventilation	Inspection	Total O&M	User Acceptance	Operational Problems	O&M Costs	Owner Components	Total Performance
1	2	1	3	3	2	5	4	14	1	3	1	3	8
2	3	5	3	3	4	3	3	13	0	1	0	3	4
3	2	4	2	3	5	4	3	15	1	3	-1	4	7
4	3	7	4	3	6	5	4	18	1	3	1	2	7
5	1	9	1	2	0	3	0	5	-1	-4	0	-2	-7
6	1	5	3	4	2	5	4	15	1	3	1	4	9
7	4	4	5	5	6	5	4	20	1	2	1	4	8
8	3	3	2	4	6	5	4	19	1	3	1	4	9
9	1	5	1	0	0	5	1	6	1	3	1	3	8
10	2	8	3	3	2	4	3	12	0	3	1	4	8
11	1	3	3	4	3	4	3	15	1	3	-1	0	3
12	1	8	3	4	3	5	3	15	1	3	1	4	9
13	1	3	1	2	4	5	4	15	1	3	0	4	8
14	4	9	4	5	3	2	4	14	1	3	1	4	9
15	6	7	3	4	6	4	4	18	1	3	1	4	9
16	1	2	2	0	0	0	1	1	1	3	1	1	6
17	2	3	1	0	1	2	0	3	1	3	1	3	8
18	2	3	1	0	1	2	0	3	1	3	1	3	8
18	2	1	3	5	3	5	4	17	1	4	1	3	9
19	2	2	4	2	4	2	3	11	1	2	1	3	7
20	1	6	3	4	2	2	3	11	-1	2	1	2	4
21	7	4	1	5	4	0	4	13	0	3	1	3	7
22	1	6	1	3	2	4	4	13	1	3	1	1	6
23	4	3	2	4	4	2	3	13	0	2	1	2	5
24	1	3	2	0	0	5	2	7	1	1	1	1	4
25	1	2	3	2	2	5	3	12	1	1	0	-4	-2
26	1	3	4	4	2	5	4	15	1	3	0	2	6
27	2	4	3	5	3	5	3	16	1	4	1	4	10
28	4	5	4	5	2	4	3	14	1	2	1	4	8
29	1	4	1	5	2	1	4	12	0	3	1	3	7
30	5	6	3	5	5	2	4	16	0	3	1	3	7
31	3	9	4	3	5	3	3	14	1	2	1	3	7
32	3	3	5	5	5	5	4	19	1	2	1	4	8
33	2	2	3	4	2	4	3	13	0	4	1	3	8
34	2	5	2	4	4	1	3	12	1	2	1	1	5
35	3	2	5	5	6	4	4	19	1	3	1	2	7
36	7	4	3	4	3	4	3	14	1	3	1	4	9
37	5	3	1	5	2	5	4	16	1	3	0	1	5
38	4	2	4	5	5	2	4	16	1	3	-1	4	7
39	1	2	5	4	6	5	4	19	1	3	1	3	8
40	1	8	3	4	6	5	4	19	1	3	1	4	9
41	2	2	1	5	3	1	3	12	1	2	1	3	7
42	1	4	1	0	0	1	0	1	1	4	1	3	9
43	1	10	4	4	5	5	4	18	1	3	1	4	9

Facility Number	Number of Tanks	Age (yrs)	Use	Bulking Agent	Maintenance Labor	Ventilation	Inspection	Total O&M	User Acceptance	Operational Problems	O&M Costs	Owner Components	Total Performance
44	1	2	3	4	3	0	4	11	1	2	1	2	6
45	2	3	3	0	3	2	3	8	0	1	1	2	4
46	2	3	3	4	3	5	3	15	1	3	1	3	8
47	1	4	1	4	1	2	2	9	1	4	1	2	8
48	1	3	2	4	0	5	3	12	1	4	1	4	10
49	1	5	3	4	5	4	4	17	1	3	1	4	9
50	1	3	3	5	4	3	4	16	0	4	1	4	9
51	1	3	4	0	4	2	3	9	0	1	1	2	4
52	1	9	3	2	4	0	0	6	1	2	1	3	7
53	1	10	2	3	2	4	3	12	1	3	1	3	8
54	1	0.5	5		Only Plans				Too Soon				
55	1	4	2	3	3	0	2	8	1	2	1	4	8
56	2	1	4	3	3	1	1	8	1	4	1	2	8
57	1	4	3	4	4	5	4	17	1	4	1	3	9
58	15	3	3	4	4	2	3	12	0	3	1	2	6
59	1	9	1	5	5	5	4	19	-1	-4	-1	-4	-10
60	2	6	4	4	1	4	4	13	1	4	1	4	10
61	1	4	1	0	3	1	2	6	0	3	1	1	5
62	2	3	3	3	3	1	3	10	1	4	1	4	10
63	1	8	2	4	2	2	2	10	1	1	1	3	6
64	2	3	3	4	2	3	3	12	1	2	1	2	6
65	5	4	1	0	3	2	2	7	0	4	1	1	6
66	1	3	2	3	2	5	3	13	0	3	1	3	7
67	9	5	3	5	2	5	4	16	1	3	0	4	8
68	2	2	2	4	3	4	4	15	0	2	0	3	5
69	1	4	1	0	0	2	1	3	0	4	1	3	8
70	1	3	2	3	2	2	4	11	1	3	1	3	8
71	3	2	2	3	0	5	3	11	1	3	0	3	7
72	2	2	3	3	2	1	3	9	0	2	0	2	4
73	6	2	4	3	4	2	4	13	1	1	0	4	6
74	2	1	3	4	2	1	4	11	0	3	1	2	6
75	2	2	3	3	3	4	2	12	1	0	1	2	4
76	4	6	2	4	4	1	3	12	0	3	1	3	7
77	2	3	4	4	3	0	3	10	1	2	1	-1	3
78	2	2	4	4	4	3	4	15	-1	4	1	2	6
79	1	2	5	3	2	1	3	9	0	2	1	4	7
80	3	3	3	3	5	3	3	14	1	4	1	4	10
81	10	1	5	2	3	4	2	11	0	2	1	3	6
82	1	4	3	3	3	5	4	15	1	3	0	3	7
83	2	3	3	4	4	5	4	17	1	4	1	3	9
84	2	1	3	5	3	3	4	15	0	4	0	1	5
85	2	6	3	4	2	5	4	15	0	4	0	4	8
86	1	1	3	0	3	1	4	8	0	4	1	1	6
87	9	2	5	4	2	5	4	15	1	4	0	4	9
88	1	1	1	5	3	3	3	14	1	4	0	3	8
89	1	3	3	0	1	5	3	9	0	3	1	3	7
90	2	2	2	3	3	5	4	15	1	3	1	4	9
91	1	9	2	1	2	4	3	10	0	2	1	2	5
92	3	6	4	2	3	1	2	8	1	3	1	4	9
93	4	3	3	5	2	3	2	12	-1	0	1	1	1

APPENDIX I:

HEALTH HAZARDS OF REMOTE SITE WASTE TREATMENT TECHNOLOGIES

A primary consideration in deploying remote site waste treatment technologies is associated health hazards. Concerns range from exposure to microbiological pathogens present in liquid, aerosol, and solid materials to the larger invertebrate and mammal vectors (flies, mosquitoes, spiders, mice, rats) often associated with waste treatment facilities.

Large composting latrines used by the Army differ from the type of composting used for sewage sludge or garden debris, since the biological activity involved does not thermally destroy pathogens. Instead, more of a mouldering activity occurs. Time and avoidance of short-circuiting are the important factors in ensuring that the finished product is safe to handle.

Vault latrines are operated primarily as holding tanks from which the waste is pumped out periodically and taken to a treatment facility. Little treatment occurs within the latrines for two reasons: (1) deodorants added are often bactericidal chemicals and (2) biological activity that occurs is anaerobic, which is less efficient than aerobic activity. However, aerated vault latrines supply oxygen to the organisms, which permits aerobic decomposition and reduction of Biochemical Oxygen Demand (BOD). Aerated vault latrine operations also require that chemicals not be added to the vault for deodorant purposes.

Chemical latrines also function as holding tanks in which chemicals liquify the waste and mask waste odors. These chemicals are bactericidal, containing compounds such as zinc, formaldehyde, and other toxic materials.

General Information and Literature Review

Human infections do not result merely because pathogens are present; a number of factors are involved. The minimal infective dose of a pathogen needed to cause disease or infection varies greatly. Only one of an organism such as helminths (tapeworms, roundworms) and viruses can cause infections in a susceptible host, while others, such as *Salmonella*, require millions of organisms to be ingested. Figure I1 illustrates typical minimal infective doses for several enteric pathogens. Actual infective doses may be lower for infants or for adults who are suffering from malnutrition or are immunologically compromised.

Human immunity level to endemic disease is also important. Many pathogens, such as enteroviruses, are extremely infective and common so that most infants acquire lifelong immunity at an early age, and additional exposures do not produce disease.

Evidence for adverse health effects from bacterial and viral diseases among people who are exposed directly to wastewater and/or wastewater aerosols is limited and often conflicting. Gunnerson[21] states that while the number of enteroviruses which can cause

[21] C. G. Gunnerson, H. I. Shuval, and S. Arlosoroff, "Health Effects of Wastewater Irrigation and Their Control in Developing Countries," *Proc. Water Reuse Symposium III* (AWWA, 1984).

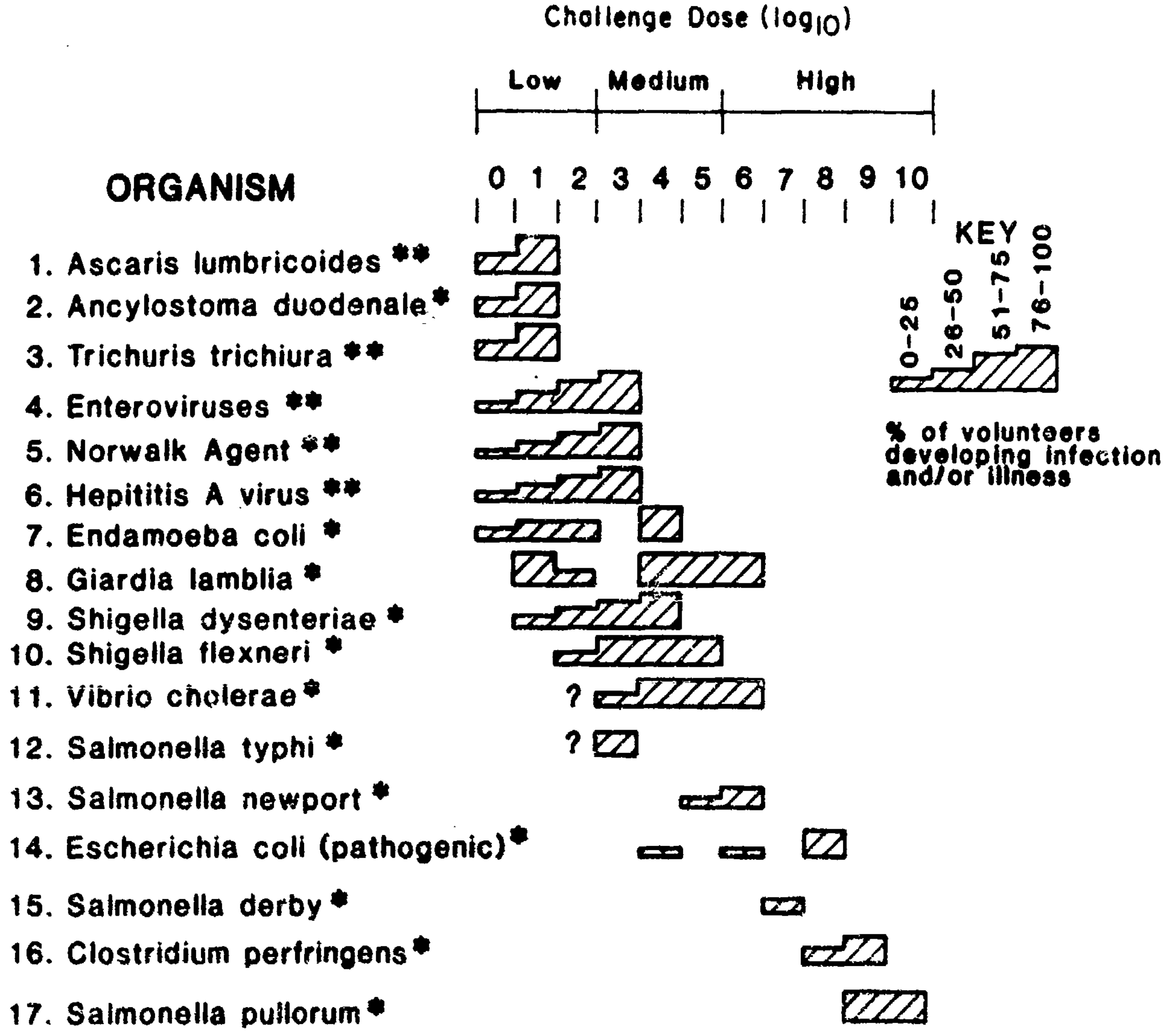

Figure 11. Minimal Infective Dose of Selected Enteric Pathogens.

infection by the fecal-oral route is rather large (about 100 discrete pathogenic viruses), it can be assumed that the excess burden of virus infection resulting from wastewater use is nil or insignificant. In contrast, man has little or no immunity to most enteric protozoans or helminths. Infestations can be long-term and cumulative.

Aerosols must be considered a possible potential problem. This topic has not been addressed in relation to aeration of vault latrines per se; however, many studies have been performed around sewage treatment plants, particularly activated sludge, and with spray irrigation of sewage effluent, with generally inconclusive results.

Environmental factors such as temperature, relative humidity, wind velocity and other atmospheric factors, and organism characteristics affect the survival and dispersal of organisms once they have become aerosolized. However, the occurrence of potentially infectious microbial aerosols does not provide evidence of associated health risks. There is no conclusive evidence that persons residing near wastewater treatment plants are subject to greater health risks.

A study by Johnson[22] which evaluated microbiological aerosols associated with land application of wastewater found that results from aerosol studies using the traditional indicator organisms underestimated pathogen levels. They found that total and fecal coliforms die off more rapidly than some other pathogens. They also found that large-volume samplers were required to obtain the requisite sensitivity for assaying bacteria and enteroviruses, due to the low levels of their concentrations. Overall conclusions were that (1) microbiological wastewater aerosols are generated by spray irrigation, (2) they do survive aerosolization, and (3) they can be transported.

Available literature on health-related aspects of composting latrines focuses on three topics: bacterial speciation and survival, virus survival, and invertebrate/vector activity.[23]

In most cases, the information compiled on these organisms strongly suggests that these latrines pose a hostile environment to each of these three groups. This has been attributed to several environmental and biochemical factors. First, the physical (temperature, humidity, etc.) and chemical (pH, ionic strength, redox, etc.) conditions of the pile matrix may not be conducive to these organisms' survival. Indeed, the toilet's environment may actually represent a toxic switch from the organism's preferred human host. Second, microbial activity within the latrine undoubtedly involves a significant measure of antagonism and predation as would be found in any normal metabolic pattern for a heterogenous culture. The final consideration is that of the lengthy delay (generally on the order of years) between waste input and final removal of the composted product. The combined effects of environmental stress and microbial competition provide a positive measure of confidence in reducing the risk of disease transmission.

Despite these expectations, protection against vector contamination and/or infestation of the latrine solids and the related health concerns likely extends no further than an open toilet seat. In short, composting latrines may be more of a health risk than

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[22] D. E. Johnson, et al., *The Evaluation of Microbiological Aerosols Associated with the Application of Wastewater to Land: Pleasanton, California*, Southwest Research Institute Report (USAMBRDL and USEPA, June 1979).

[23] R. C. Cooper and C. G. Golueke, "Survival of Enteric Bacteria and Viruses in Compost and Its Leachate," *Compost Science/Land Utilization* (March-April 1979), pp 29-35; R. C. Cooper, A. W. Olivieri, R. E. Danielson, P. G. Badger, R. C. Spear, and S. Selvin, *Assessment of Risk Associated with Water-Related Infectious Agents for Military Field Water Supplies* (Sanitary Engineering and Environmental Research Laboratory, University of Calfornia, Richmond Field Station, January 1984); M. De Bertoldi, U. Citernesi, and M. Griselli, "Bulking Agents in Sludge Composting," *Compost Science/Land Utilization* (January-February 1980), pp 32-35; D. L. Dindal, *The Decomposer Food Web: Only the Beginning* (JG Press, Inc., 1980), pp 1-13; M. Fogel (consultant to Clivus Multrum), letter to E. D. Smith (USA-CERL) (Newton, MA, March 1984); W. L. Gaby, *Evaluation of Health Hazards Associated with Solid Waste/Sewage Sludge Mixtures* (U.S. Department of Commerce, April 1975), pp 1-11; C. G. Golueke, "When is Compost 'Safe?'," *BioCycle*, Vol 23, No. 2 (March-April 1982), pp 28-36; H. W. Nichols, *Analysis of Bacterial Populations in the Final Product of the Clivus Multrum* (Center for the Biology of Natural Systems, December 7, 1976), pp 1-16; A. W. Olivieri, *Risk-Benefit Analysis: On-Site Waste Treatment and Disposal Systems*, Doctoral Dissertation (University of Calfifornia, Berkeley, CA, 1982); R. J. Scholze, E. D. Smith, and J. T. Bandy, "Health Hazard Assessment of Waterless Remote Site Waste Management Technologies," *Proceedings of the ASCE Specialty Conference on Environmental Engineering* (ASCE, 1985a), p 963.

more conventional wastewater treatment systems, such as flush latrines, but are comparable to other remote site waste technologies.

Monitoring and Experimentation

Exposure Study

A study at Fort Leonard Wood, MO, investigated the potential for exposure of latrine users and maintenance personnel to pathogenic bacteria and other organisms in aerosols and solid and liquid wastes.[24] The study was conducted at four types of remote site latrines: composting latrines, a standard vault latrine, a chemical latrine, and an aerated vault latrine.

Liquid, solid, and aerosol samples were analyzed for total coliform and other parameters. Results showed low levels of coliform in the composting latrine liquid, while the vault latrines and chemical latrines showed high levels, as would be expected in what is basically raw sewage. Solids from the finished compost chamber had average values of 3300 total coliform per gram in one unit and 1200 per gram in the other unit. During the remainder of the time period, values of less than 50 total coliform per gram were recorded. Total coliform counts of the air samples were all less than two organisms per cubic foot of air. Air samples taken in flush toilet lavatories for comparison purposes were negative when analyzed for total and fecal coliform. Gas analyses indicated no methane or hydrogen sulfide and showed ammonia levels of between 1 and 3 ppm.

Pathogen Destruction

The usual standard for determining whether compost is free of pathogens has been attaining 55°C for four consecutive days in the case of sewage sludge. Other combinations of time and temperature are also appropriate for pathogen destruction. Figure 12 shows the influence of time and temperature on selected pathogens found in night soil and sludge. Large composting latrines do not reach that temperature level (they are usually about ambient) and must rely on retention time and biological interactions for appropriate treatment. In a temperate or tropical climate, a 3-month retention time should destroy most pathogens.

For determining the extent of pathogen destruction in sewage sludge, *Ascaris* (a parasitic helminth) is one of the intestinal parasites often used as an indicator of a treatment process' effectiveness. *Ascaris* ova are extremely hardy and may remain viable for years. However, in the United States, this parameter may not always be appropriate. Coliforms, both fecal and total, are the usual indicators of potential danger to humans. Survival of pathogens in feces and night soil may be assumed to be similar to survival in sewage sludges. Feachem[25] has supplied information (shown in Table 11) that roughly indicates the survival time for several pathogens.

Table 12 summarizes survival time in soils for various pathogens. The environment within a composting latrine waste mass is similar to that of sewage sludge and night

[24] R. J. Scholze, E. D. Smith, and J. T. Bandy, "Health Hazard Assessment of Waterless Remote Site Waste Management Technologies."

[25] R. G. Feachem, *Sanitation and Disease, Health Aspects of Excreta and Wastewater Management* (World Bank, John Wiley and Sons, 1983).

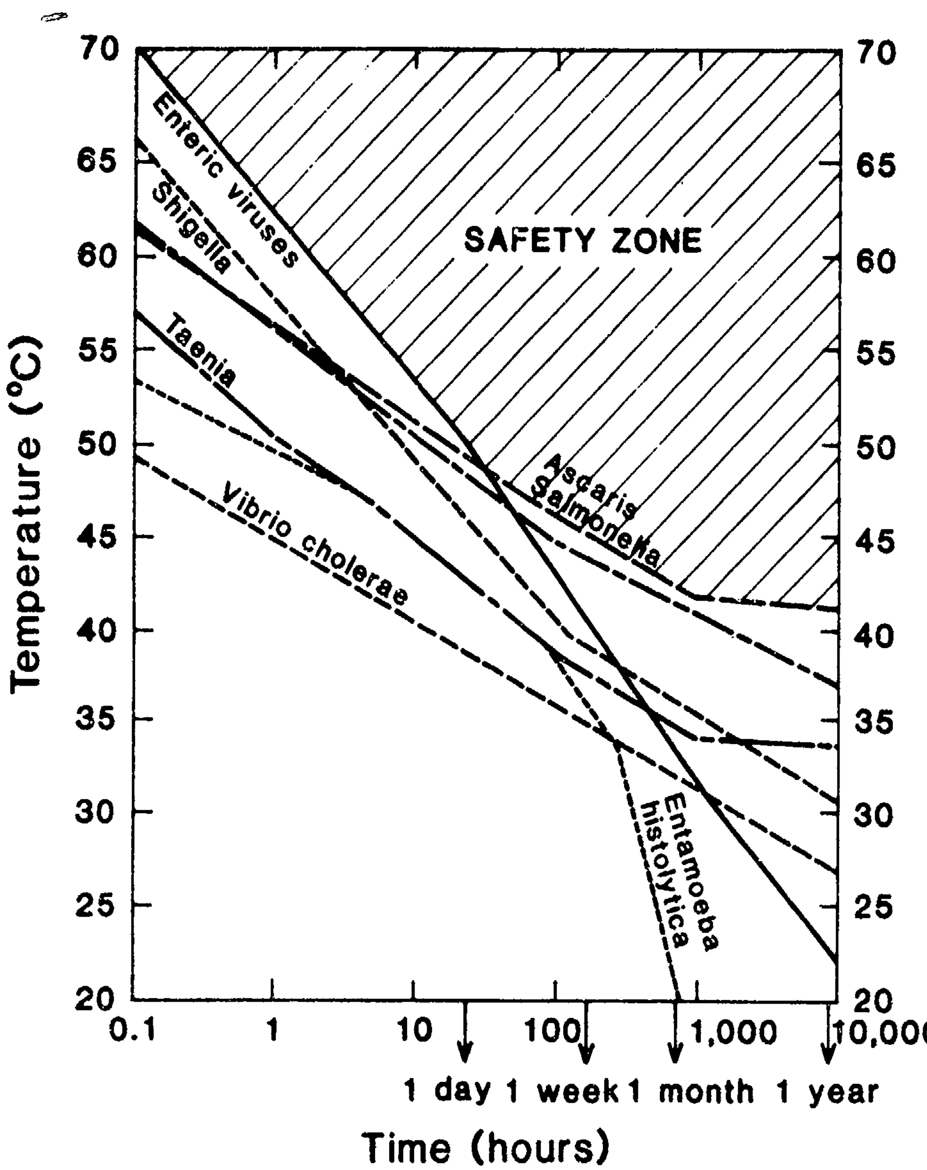

Figure 12. Influence of time and temperature on selected pathogens in night soil and sludge.

soil. Therefore, the effect of time on pathogens is expected to be similar. The environment within the composting chamber is a potential health hazard. Large numbers of potential pathogens are present in the raw waste section of the composting latrine, as shown by the numbers detected during the waste sampling exercise and the survival times expressed in the tables. Protective measures must be taken when maintenance personnel are raking or stirring the pile of composting waste and bulking agent. The finished compost section should also be considered a potential source of hazardous materials; thus, proper procedures should be followed, even though the number of pathogens has been greatly reduced.

Monitoring values of fecal coliform from the composting latrines at Fort Jackson varied tremendously, even within the same unit, and showed values that ranged from <2 to 24,000 per 100-mL sample. Channeling may have been the reason for such varied values. However, these numbers emphasize the importance of proper maintenance procedures for composting latrines.

Table I1

Survival Times of Excreted Pathogens in Feces, Night Soil, and Sludge at 20 to 30°C
(From R. G. Feachem, *Sanitation and Disease, Health Aspects of Excreta and Wastewater Management* [World Bank, John Wiley and Sons, 1983].)

Pathogen	Survival Time (Days)
Viruses	
Enteroviruses	<100 but usually <20
Bacteria	
Fecal coliforms	<90 but usually <50
Salmonella spp.	<60 but usually <30
Shigella spp.	<30 but usually <10
Vibrio cholerae	<30 but usually <5
Protozoa	
Entamoeba histolytica cysts	<30 but usually <15
Helminths	
Ascaris lumbricoides eggs	Many months

Table I2

Survival Times of Excreted Pathogens in Soil at 20 to 30°C
(From R. G. Feachem *Sanitation and Disease, Health Aspects of Excreta and Wastewater Management* [World Bank, John Wiley and Sons, 1983].)

Pathogen	Survival Time (Days)
Viruses	
Enteroviruses	<100 but usually <20
Bacteria	
Fecal coliforms	<70 but usually <20
Salmonella spp.	<70 but usually <20
Vibrio cholerae	<20 but usually <10
Protozoa	
Entamoeba histolytica cysts	<20 but usually <10
Helminths	
Ascaris lumbricoides eggs	Many months

APPENDIX J:

INPUT WASTE CHARACTERIZATION

Domestic composting latrine applications require a supplemental system to handle greywater generated within the home. Greywater includes water from personal bathing and kitchen use, laundry, etc. However, a remote site military waste management system has no need for this type of system.

Per capita fecal waste mass discharges average about 175 to 200 wet grams per day which corresponds to a volume of 150 to 170 mL. Between 66 and 80 percent of the wet fecal mass is made up of water. The organic carbon and nitrogen fractions of the dry fecal material will typically yield a C/N ratio of 5:1 to 10:1.

The addition of toilet paper with each fecal waste input would affect both the C/N ratio and the wet and dry volumes. Both the wet and dry volumes would increase by about 50 percent; the C/N ratio should increase to a range of 8:1 to 10:1 due to the rich carbon content of the paper material.

Per capita urine discharge volumes typically range from 1200 to 1500 mL. This liquid has a high salt content, which constitutes much of the dry residue volume and mass, and a total nitrogen concentration of 7200 to 9000 mg N l^{-1}. However, the organic carbon level within urine is generally low; thus, the C/N ratio is considerably less than that of the fecal waste segment. Tables J1 and J2 summarize the expected character and composition of the involved fecal and urine additions.

Table J3 provides information on the characteristics of wet and dry combined wastes. The total volume, which includes fecal, urine, and paper wastes, has an approximate value of 1500 mL per capita per day. A "per-use" wet-phase discharge volume of 375 mL may be derived using an assumption of four "uses" per capita per day. When the moisture has been removed, this waste volume would be reduced to about 100 mL per capita per day, or 25 mL per use. For the dry mass of the combined waste material, the typical "per-use" value of 30 g will have an approximate inorganic-organic distribution of 50/50 due to the high salt content of the urine segment.

The relative balance between these two incoming waste forms (based on volumetric loadings) will have a corresponding effect on several operational concerns, including:

1. The influx of new bacterial seed for the pile

2. The moisture balance within the pile

3. The organic versus inorganic composition of the pile

4. The thermodynamic characteristics of the pile, relative to such factors as its exothermic heat flux and moisture evaporation.

Table J1

Per Capita
Fecal Waste Characteristics

Quality

Parameter	**Value**	**Ref.**
Wet Mass	175 → 200 g/day	Gotaas, 1956; Keefer, 1940
Wet Volume	150 → 170 mL/day	Gotaas, 1956; Keefer, 1940
Dry Mass	35 → 70 g/day	Gotaas, 1956; Keefer, 1940
Dry Volume	25 → 50 mL/day	Gotaas, 1956; Keefer, 1940

Composition

Parameter	**Value**	**Ref.**
Moisture (Wet Basis)	66 → 88%	Gotaas, 1956
Organics (Dry Basis)	88 → 97%	Gotaas, 1956
Nitrogen (Dry Basis)	5 → 7%	Gotaas, 1956
P_2O_5 (Dry)	3 → 5.4%	Gotaas, 1956
K_2O (Dry)	1 → 2.5%	Gotaas, 1956
Carbon (Dry)	40 → 55%	Gotaas, 1956
CaO (Dry)	4 → 5%	Gotaas, 1956
Carbon:Nitrogen (Dry)	5:1 → 10:1	Gotaas, 1956

Table J2

Per Capita
Urine Waste Characteristics

Quality

Parameter	Value	Ref.
Wet Mass	1235 → 1575 g/day	Gotaas, 1956; Keefer, 1940
Wet Volume	1200 → 1500 mL/day	Gotaas, 1956; Keefer, 1940
Dry Mass	50 → 100 g/day	Gotaas, 1956; Keefer, 1940
Dry Volume	35 → 70 mL/day	Gotaas, 1956; Keefer, 1940

Composition

Parameter	Value	Ref.
Moisture (Wet Basis)	93 → 96%	Gotaas, 1956; Keefer, 1940
Organics (Dry Basis)	65 → 85%	Gotaas, 1956; Keefer, 1940
Nitrogen (Dry Basis)	15 → 19%	Gotaas, 1956; Keefer, 1940
P_2O_5 (Dry)	3.5 → 5%	Gotaas, 1956; Keefer, 1940
K_2O (Dry)	3 → 4.5%	Gotaas, 1956; Keefer, 1940
Carbon (Dry)	11 → 17%	Gotaas, 1956; Keefer, 1940
CaO (Dry)	4.5 → 6%	Gotaas, 1956; Keefer, 1940
Carbon:Nitrogen (Dry)	<1:1	Gotaas, 1956; Keefer, 1940 Estimated

Table J3

Estimated Per Capita
Combined Waste Characteristics

Wet Form

Parameter	Value
Wet Mass	1410 - 1775 gm/day
Wet Volume	1425 - 1725 mL/day

Dry Form

Parameter	Value
Dry Mass	85 - 170 gm/day
Dry Volume	73 - 145 mL/day

APPENDIX K:

SUGGESTED SCOPE OF WORK FOR CONTRACTOR O&M OF LARGE COMPOSTING LATRINES (TOILETS)

*Please note this SOW does not address the daily maintenance routine at the facility, which also is very important. See pp 22, 24, and 26 for special considerations by responsible parties. Daily maintenance includes: changing toilet paper, cleaning seat and chute, sweeping floor, etc.

Background

Composting latrines, specifically large composting latrines, have been used for more than thirty years. Most applications have been in private residences. However, their use in public facilities has been increasing.

Composting latrines (See Figure 6) are designed to function aerobically, i.e., in the presence of oxygen. During the process, bacteria, fungi, and other saprophytic organisms convert organic materials into a more stable form. Large, continuous composting latrines rely on time and a hostile environment for pathogen destruction. No water is used in the process or for flushing, so only night soil (fecal matter, urine, toilet paper, and bulking agent) is introduced into the composting chamber.

Waste treatment by compost latrines generally requires 1 to 2 years. The process takes place in a large chamber which is positioned on a slope so that waste slowly moves to a bottom removal area. Wastes are combined with bulking agents such as wood shavings to form a mass that continuously decomposes. The bulking agents aid composting physically and biologically. A vent pipe and fan constantly remove water vapor, carbon dioxide, and other gases from the system supplying substantial evaporation.

Performance of composting latrines depends on proper technique (O & M) and efficient removal of excess liquid. Failure to properly perform this critical operation and maintenance will result in process failure.

Introduction

The Contractor shall have copies of the USA-CERL Technical Report "Technology for Waste Treatment at Remote Army Sites" and the manufacturer's operation and maintenance manuals.

Tasks

A. Materials

Required materials include, but are not limited to:

1. Bulking agent. Acceptable materials include wood shavings and very coarse sawdust from wood which is not toxic to the microorganisms in the composting latrine. For example, pine is acceptable, cedar is not acceptable. Contractor will supply the Contracting Officer acceptable proof that acceptable quantities of dry bulking agent are

readily available. Questions concerning quality and acceptability of bulking agent will be answered by the Contracting Officer. USA-CERL, the manufacturer, and the DEH are sources of information, if necessary.

Bulking agent (will/will not) be stored on-site. If stored on-site, a dry container must be supplied to maintain bulking agent in a dry condition.

2. Tools. Required tools include rakes or cultivators capable of moving mixture of waste and bulking agent easily, shovels or similar implements to remove finished compost, high-strength sealable plastic bags for removal of finished compost, and personal protective gear such as dust masks, rubber or disposable gloves, boots, etc. Implements will be exposed to raw human waste, thus mandating that health considerations be closely followed. Refer to p 21, p 58, Chapter 7, Appendix I, and appropriate local health agencies for suggested immunizations and handling practices.

B. The Contractor shall perform the following:

1. The Contractor shall add bulking agent at a frequency of (daily) (two/three times per week). Addition shall be down each latrine chute. Quantities are dependent upon use. Guidelines to follow are: 1-2 cubic feet per 1000 uses or 1 gallon per 100 uses. Typically, two quarts down each chute as most military installations have two chutes per tank.

2. Monthly, the following shall be performed:

a. Inspect the height of the waste pile through the waste access door on the front of the tank. If the air channels are exposed, add enough bulking agent to cover them. Rake bulking agent into pile.

b. Visually inspect the waste pile to determine if it is moist. The waste pile should be moist with a crumbly texture. If it appears to be compacted, increase the amount of bulking agent, but not more than four quarts per day.

If the pile seems dry, especially near the front, then add water. This will be unlikely at any training range sites as urine is the primary input.

Water daily until water appears in the liquid end-product chamber at the front of the tank's bottom.

If the pile is too wet, add bulking agent each week until the pile seems moist and crumbly.

If the waste appears to be piling up and clogging the latrine chutes, then rake over the pile until it is evenly distributed.

c. Pile should be raked and mixed.

d. For ventilation, every month, listen to hear if the fan is operating; these fans should always be operating and not turned off.

Check the draft by holding a blown-out match near the edge of the toilet seat while lifting the lid slightly. The smoke should be drawn into the latrine. If not, check the fan or clean the vent stack. Also check for debris or insect buildup in the screen. Check the ventilation further by holding a blown-out match near the air inlets on

the end-product access door on the front of the tank. If the smoke does not enter the tank, open the end-product access door and check to see if liquid or compost is blocking the air duct openings in the front baffle. If so, clean the openings.

e. Excess liquid should be drained or pumped automatically ach line. There will be no maintenance other than keeping the drain line clea the pump operational.

Under no circumstances should the liquid be allowed to accumulate high enough to cover the air intakes in the end-product chamber. If liquid level rises, unclog screen in liquid baffle.

3. On a semi-annual basis, the following shall be performed:

a. When top of waste pile is within two (2) feet of top of tank, remove about 10 (ten) cubic feet of end product from end product chamber. Remove end product with shovel, place into plastic bag and dispose. Disposal shall be [on installation site to be designated by DEH/off the installation at Contractor's site]. Make sure the waste pile settles immediately to the bottom of the tank. Push down if necessary through the waste access door and/or the latrine chute, using a pipe or rod.

4. Yearly, perform the following:

a. Remove fan and clean vent stack.

b. Inspect the tank support.

Reports

Contractor shall maintain a notebook or similar file on each composting latrine. The notebook shall contain all steps followed during maintenance; list amounts, dates and frequency of bulking agent addition; list dates and amounts removed of finished compost product; and dates and activities performed. If malfunctions or other problems exist, they shall be noted and the responsible party shall be contacted by the Contractor for correction if out of the jurisdiction of the Contractor.

Copies of the notebook pages shall be submitted to the Contracting Officer monthly. The Contracting Officer may keep them or send them to the appropriate contact at DEH.

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None.

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